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STUDIES ON THE ROLE OF COBALT IN SHEEP NUTRITION[1]

S. N. Ray, W. C. Weir, A. L. Pope, G. Bohstedt
and P. H. Phillips
University of Wisconsin

FOLLOWING the pioneer work of Marston (1935), Lines (1935), and Underwood and Filmer (1935), it is now definitely established that cobalt is an essential element in the nutrition of at least sheep and cattle. Since that time, the cobalt-deficient areas have been found to be widespread throughout the world, but very little has been learned about the specific function of cobalt in the animal body. The main symptom of cobalt deficiency is anorexia followed by loss in weight, anemia, and death. Work with animals like rats, guinea pigs, etc., has shown that excessive cobalt ingestion leads to polycythemia (Orton, 1936; Stare and Elvehjem, 1933). It may be postulated that cobalt deficiency in other species will produce anemia and will thereby cause degeneration, emaciation, and death. The objection to this theory is that, as yet, cobalt deficiency has never been produced in any species of animals except the ruminants. Moreover, cattle and sheep behave quite differently from monogastric animals as it is is practically impossible to produce polycythemia in the former by cobalt feeding (Josland. 1937; Geyer *et al.*, 1945; Hopkirk, 1937). This difference can now be readily understood from the work of Comar *et al.*, (1946), who showed that ruminants absorb only 0.25 percent of orally administered cobalt.

When it is remembered that only 0.1 mg. cobalt per day need be given to an adult sheep for maintenance (Underwood and Harvey, 1937), and considering the low absorption of this mineral, it appears therefore that either the very minute quantity of absorbed cobalt has tremendous physiological action or that the good effects of cobalt administration arise from its influence on reactions in the alimentary canal of ruminants. The element may be essential for the metabolism of the microflora present in the rumen and in its absence the protozoa and bacteria in the rumen may fail to produce substances essential for the health of their host. This hypothesis is supported by the observation of McCance and Widdowson (1944), that cobalt is not curative when given to ruminants by injections but only when given orally. Comar *et al.* (loc. cit.) showed that when cobalt is injected into cattle, 5 percent was retained inside the body but none of the injected cobalt appeared in the rumen, omasum, or reticulum contents. Herein perhaps lies the failure of the efficiency of injected cobalt.

[1] Published with the approval of the Director of the Wisconsin Agricultural Experiment Station, Madison, Wisconsin; From the Biochemistry and Animal Husbandry Departments. This work was supported in part by the Wisconsin Alumni Research Foundation.

Assuming that cobalt is related to rumen function, the question arises as to its possible role. It is curious that many of the symptoms of cobalt deficiency are similar to well-known vitamin deficiency symptoms. Thus anorexia, the first noticeable symptom of cobalt deficiency, is also associated with vitamin B_1 deficiency. Another symptom of cobalt deficiency is anemia which is also produced by the deficiency of several members of vitamin-B complex, viz. folic acid, pyridoxine, riboflavin, niacin, biotin, and pantothenic acid. It is now well recognized that ruminants are not dependent on their feed for all these vitamins, as they are produced in the rumen in large quantities (McElroy and Goss, 1939). It is, therefore, quite possible that in the absence of cobalt some of these vitamins may not be produced in adequate quantities in the rumen, thus bringing about loss in weight and other degeneration symptoms. This work was, therefore, taken in hand in order to examine the efficacy of certain vitamin therapy in cobalt-deficient lambs.

Experimental

Twenty-five young lambs aged 6 to 7 months were available for this experiment. Eleven of these had been on a cobalt deficient ration since their birth.[2] The rest were purchased from 2 farms, where cobalt-deficient symptoms had been prevalent and no cobalt therapy was used. Owing to the small number of animals, only 5 groups were run, 4 groups containing in each 3 purchased lambs and 2 lambs of known dietary origin; the fifth group contained 2 lambs of the former and 3 lambs of the latter category. The animals in all the groups were given daily per head 1 lb. cobalt-deficient hay (Co content = 0.032 ppm) and as much of a mixture of 80 percent corn and 20 percent of corn gluten meal as they would eat every day. Daily records of the amount of concentrate eaten by each group were kept. Five groups were divided as follows: Group I—control, basal ration only; Group II—basal ration plus 4.55 mg. thiamin per head; Group III—basal ration plus 2.6 mg. folic acid per head; Group IV—basal ration plus 100 mg. pyridoxine per head, and group V—basal ration plus a capsule containing 17.5 mg. of cobalt sulphate per head. The vitamins were injected and the capsules fed twice weekly. Each quantity of vitamins was dissolved in 1 ml. of distilled water and was injected intramuscularly. After 5 weeks of twice-weekly treatment, daily injections of the proper aliquot quantities of the vitamins were tried and in order to check the effect of excessive handling, the control (group I) and cobalt (group V) animals were given daily injections of 1 cc. of distilled water. Since the daily injections did not prove to be necessary, and the animals of all the groups including the cobalt group, lost weight, the daily injections were discontinued after one week and the previous twice-

[2] Dams had received only roughage used in basal ration since 1 to 3 months prior to lambing.

weekly treatments were resumed, with the exception that the animals of the control and cobalt groups were given twice-weekly injections of 1 cc. distilled water. The experiment was discontinued after 9 weeks. The results are summarized in table 1. Two animals, one in group III and the other in group IV, died during the experimental period, consequently the results of these two groups represent the average of 4 animals only.

Results and Discussion

The beneficial effect of cobalt administration on the live weight increase is evident from the figures given in table 1 (and figure 1). Thiamin treated animals also showed definite gains in body weight. This was especially

TABLE 1. EFFECT OF VITAMINS AND COBALT SUPPLEMENTS ON THE AVERAGE WEIGHT AND HEMOGLOBIN CONTENT OF COBALT DEFICIENT LAMBS

Group and type of data		Increase in body weight	Hb content	Percentage deviation of Hb from initial value
		lb.	gm./100 ml. blood	percent
I. Control	Average	9.5	7.49	−26.9
	Range	−15 to +23	5.65–8.36	
II. Thiamin	Average	16.8	5.14	−50.9
	Range	−16 to +31	2.40–7.59	
III. Folic acid[1–2]	Average	5.3	7.61	−27.0
	Range	−16 to +30	4.68–9.57	
IV. Pyridoxine[1]	Average	11.7	5.81	−38.8
	Range	−16 to +26	3.35–8.63	
V. Cobalt	Average	29.0	8.46	−18.7
	Range	+28 to +31	7.43–9.26	

[1] Average of 4 animals.

[2] From 5th to 7th week, each of these animals received daily in capsule B_1 1.6 mg., B_2 2.4 mg., pyridoxine 40 mg., Ca pantothenate 10 mg., niacin 8 mg., P.A.B. 120 mg., choline 0.4 gm., inositol 100 mg., and injections of biotin 0.16 mg. and folic acid 1.00 mg. From the 7th to 8th week, each animal received twice weekly injections of B_1 5 mg., B_2 9.5 mg., pyridoxine 150 mg., Ca pantothenate 35 mg., and folic acid 2.63 mg.

noticeable after 5 weeks when the control animals were losing weight, but the group II (B_1 treated) animals were consistently gaining weight (figure 1). Pyridoxine and folic acid fed animals fared very similarly to the control animals as far as growth was concerned.

The feed intake figures more or less follow the growth rates. The average daily intake of concentrate in pounds per head in the various groups were:

Group I—1.37, II—1.62, III—1.3, IV—1.66, and V—2.13. These results are in agreement with the experience of other workers that ingestion of cobalt brought about an improvement in the appetite of the animals and gain in weight followed. Thiamin injection, which gave a better gain in weight, also bolstered up the appetite over that of the control animals. An

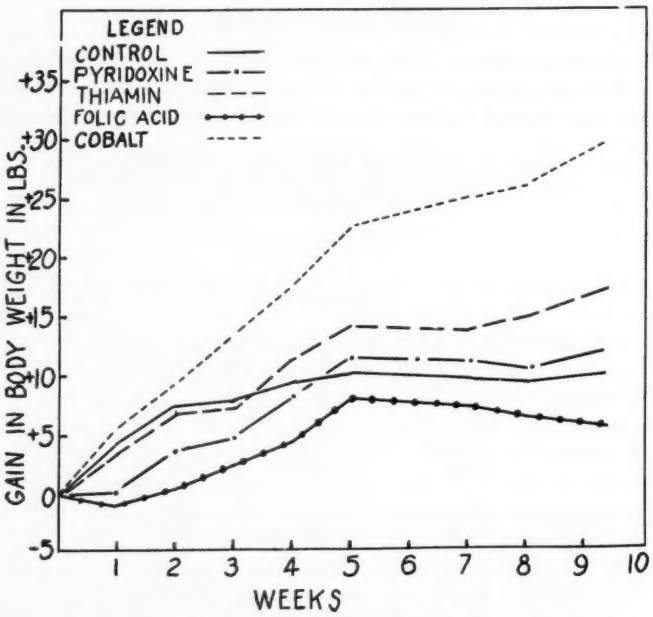

Figure 1. Rate of gain in weight in pounds of the lambs in the various groups in the 1st experiment.

exception seems to be in the case of pyridoxine treated animals, which appeared to have a better appetite, not followed however by a proportionate increase in body weight.

Since the animals of the folic acid group were not gaining weight rapidly, it was decided to give all the B-complex vitamins to 3 animals of this group. The dosages of the respective vitamins are shown in the footnote below table 1. This therapy, however, did not improve the growth rate. The inability of the thiamin supplied in the mixture to enhance the growth rate in these 3 animals is rather strange, but it is possible that the vitamins given by mouth may not be as active as when given by injection and thus the

amounts supplied were probably insufficient to bring about any improvement. When injections of B_1, B_2, B_6, folic acid, and pantothenic acid were given during the last two weeks of the experiment, the animals were perhaps too far depleted to respond quickly to any treatment.

Turning to the hemoglobin figures, it will be noticed that all the groups suffered a decrease in the hemoglobin values (figure 2). The cobalt group of animals showed the least decrease, but even in these lambs the final values were well below the accepted normal figure. This lag in the rise of hemo-

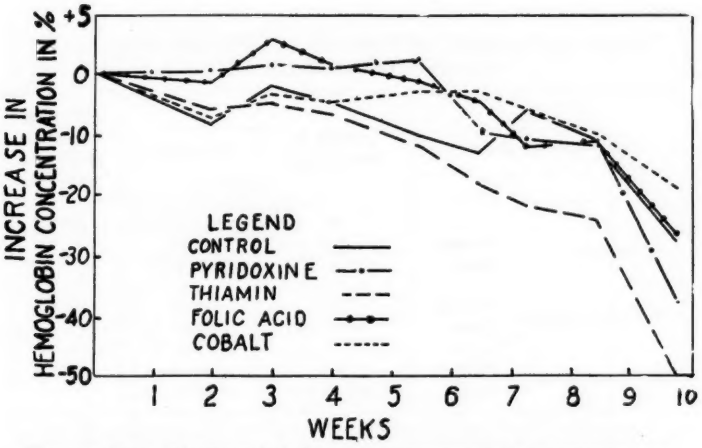

Figure 2. Rate of increase in hemoglobin concentration in percentage over the initial values in the various groups of the 1st experiment.

globin concentration had been noticed in earlier work in this department (Pope *et al.*, 1947). The most noticeable feature was, however, the development of severe anemia in the thiamin treated animals. The hemoglobin content of the blood of these animals diminished steadily from the beginning of the experiment and never showed the variation observed by the other lots (figure 2). Further, as soon as the injections were stopped, the hemoglobin concentrations increased within a week by 30 to 40 percent in all the animals. Since the weights of these animals increased during this period, it may be concluded that the improvements in the hemoglobin figures were not caused by dehydration of the blood. The reason of this exaggerated anemia through thiamin treatment cannot be explained.

In this connection it may be interesting to recall the work of Filmer (1933), who found that raw liver in dosage of 100 gm. a day had a good curative

effect on cobalt deficient animals and that the liver ash was ineffective. Obviously some of the organic components, probably the vitamins, in the liver, were the curative agents.

Cobalt given by mouth seemed to have but little effect on hemoglobin formation. Hence it was postulated that cobalt may have dual effect in the body. The primary one may occur in the rumen, where it may be connected with the formation of vitamins. But in addition to this, it may have some influence within the hemopoietic tissues as well. According to Comar *et al.* (1946), only 0.25 percent of orally administered cobalt is absorbed by the

TABLE 2. COMPARATIVE EFFICACY OF INJECTED AND ORALLY ADMINISTERED COBALT SALTS

Group and type of data		Increase in body weight	Hb content	Percentage deviation of Hb from initial value
		lb.	gm./100 cc blood	*percent*
I. Control	Average	3.8	9.35	+28.0
	Range	−15 to +19	7.72–10.81	
II. Cobalt injection	Average	9.9	10.15	+58.0
	Range	−6 to +21	7.08–11.71	
III. Cobalt per os	Average	15.0	11.19	+61.2
	Range	+8 to +20	10.73–11.37	

ruminants, therefore the possibility existed that a sufficient amount of cobalt was not being absorbed by our cobalt treated animals to bring about a quick hemoglobin response. Since Comar *et al.* (1946) also reported that 5 percent of injected cobalt was retained by animals, a second experiment was conducted to determine the effect of cobalt therapy by both oral and by intramuscular administration.

The surviving animals of lots I to IV in the vitamin therapy studies were then realloted into 3 groups on the basis of previous dietary history. Group I consisting of 6 animals constituted the control group, each animal in it was given an injection of 4 cc. of water containing 5.2 mg. of sodium sulfate twice weekly. Group II also contained 6 animals, each of which received twice-a-week injections of 4.0 cc. of water containing 17.6 mg. of $CoSO_4 \cdot 7H_2O$. Group III contained 5 animals, each of which received twice a week a capsule containing 17.6 mg. of $CoSO_4 \cdot 7H_2O$, as well as an injection of 4 cc. of a solution containing 5.2 mg. of Na_2SO_4. The injections were administered each time in 4 different parts of the body so as to insure maximum

absorption. The object of the sodium sulfate solution injection was to maintain isotonicity with the cobalt sulfate solution injected. Lot V animals of the first experiment which received cobalt capsules were continued as controls, but they were not given further injections of water. This second experiment was continued for 7 weeks and the results are presented in table 2. One animal in each of the groups died during this period and the results are, therefore, averages of 5 animals for each of the groups I and II, and 4 for group III.

The beneficial effect of the administration of cobalt by mouth on the body weight of the animals was again demonstrated in this series of experiments (figure 3). Unlike McCance and Widdowson (1944), we found that the injection of cobalt salts had a beneficial effect although of smaller degree than

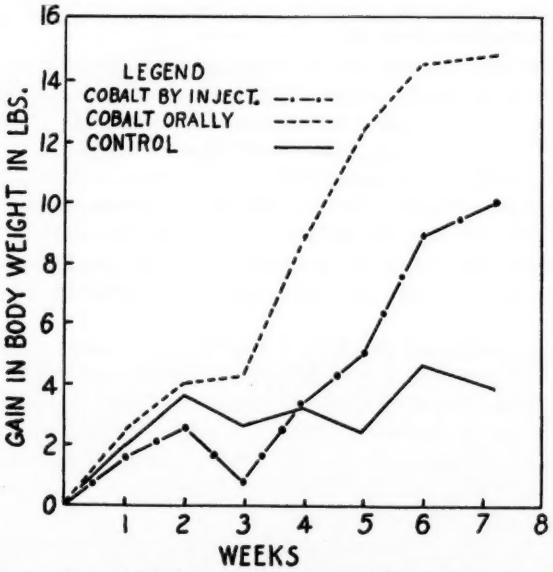

Figure 3. Rate of gain in weight in pounds of the lambs in the various groups of the 2nd experiment.

that seen in the oral therapy. The most common response was the increase in the hemoglobin concentration in all the groups irrespective of method of cobalt administration. Even some of the animals in the control groups, which were in a very moribund condition, developed quite normal hemoglobin values. These results are rather surprising, but agree with the observations

of the Australian workers (Askew, 1939; Bell, 1937) who found that blood counts and hemoglobin concentration did not correlate with the degree of sickness, nor did the administration of cobalt appear to stimulate the production of red cells in abnormal numbers.

The injection of cobalt salts did not appear to have a pronounced influence on the hemoglobin formation since the final hemoglobin concentrations in both the injected and orally treated groups were very nearly identical (compare curves in figure 3).

In view of effect of cobalt on the production of polycythemia in nonruminants (Orton, 1936; Stare and Elvehjem, 1933), the inability of injected cobalt salts to bring about a noticeable response in the hemoglobin regeneration was rather strange. It is possible that anemia in cobalt deficient sheep is of a secondary nature and occurs as the result of anorexia and general malnutrition. It is likewise possible that cobalt may not have any direct effect on hemoglobin formation.

An interesting reaction was the behavior in the various groups of the lambs which had previously been treated with thiamin. The control group of the second series included one such lamb. This animal gained 19 pounds in body weight in 7 weeks, whereas the other animals in that group and which had no thiamin treatment, gained only $+8$ to -15 pounds. Animals in other groups which had previous thiamin supplementation showed the greatest gains and were also the best animals in their respective groups. It appears, therefore, that thiamin treatment brought about a beneficial effect, which persisted for some time, even after the supplementation had been stopped.

In order to safeguard the effects of other mineral elements, generally associated with hemopoiesis, we administered twice a week to a number of animals in each group of the second series of experiments, capsules containing 0.6 gm. of ferrous ammonium sulphate, 0.0175 gm. of copper sulphate, and 0.118 gm. of manganese chloride. No difference, in either body weight or hemoglobin increase, was seen between the animals thus supplemented and the other animals of the same groups.

After the second experiment, all the surviving lambs were killed along with 4 young lambs of the same age, but which had received cobaltized salt (12.7 gm. $CoSO_4 \cdot 7H_2O$ per 25 lb. salt) since birth. The livers of all these animals were carefully extirpated, dried between filter paper, and weighed. These tissues were then dried, ground, and their cobalt content was estimated according to the method of Kidson *et al.* (1936). Pancreas and spleen from a number of animals were also examined for their cobalt content. The results are given in table 3.

It will be noticed that the lambs in the cobalt-deficient control group had

very little cobalt in their tissues. The values found by us are similar to those given by other workers for such animals (Underwood and Harvey, 1937; Askew and Dixon, 1937). Administration of cobalt salts by mouth for 7 weeks only, was quite effective in bringing up the cobalt concentration in the liver to values reported to be normal by the above workers. Our data obtained for normal animals are a little higher than those given by the Aus-

TABLE 3. CONCENTRATION OF COBALT IN THE ORGANS OF NORMAL, DEFICIENT, AND TREATED LAMBS

Group and type of data		Concentration of cobalt in ppm of dried tissue		
		Liver	Spleen	Pancreas
I. None	Average	0.025	0.023	0.021
	Range	0.020–0.030	0.022–0.023	
II. Cobalt sulphate (injected for 7 weeks)	Average	1.94	0.39	—
	Range	1.18–2.63	—	—
III. Cobalt sulphate (given by mouth for 7 weeks)	Average	0.226	—	—
	Range	0.185–0.280	—	—
IV. Cobalt sulphate (given by mouth for 17 weeks)	Average	0.288	0.052	0.078
	Range	0.240–0.305	0.031–0.076	—
V. Normal (cobaltized salt, average of 4 lambs)	Average	0.47	—	—
	Range	0.23–0.83	—	—

tralian workers, i.e., 0.47 ppm instead of 0.23–0.28 ppm. This may be due to the fact that these lambs had received cobaltized salt since birth.

The concentration of cobalt in the tissues of lambs to which cobalt sulphate was given intramuscularly was about 8 to 9 times that of the orally treated group. This observation is in accord with the isotope studies of Comar *et al.* (1946). Despite the high concentration of cobalt in the tissues, these cobalt injected lambs showed much slower rate of growth than the orally treated animals. It may be concluded again that the chief function of this mineral is outside the body proper, *i.e.*, probably somewhere in the alimentary tract. It may be seen from figure 3 that these injected animals showed little or no growth during the first 4 weeks of their treatment, however the growth rate increased considerably thereafter. It is possible that after prolonged treatment with injections of cobalt salts, some of this mineral might have been secreted into the rumen, probably by way of saliva and thus produced a stimulation of growth.

On autopsy, the livers of a number of animals in the control group were found to be mottled and pliable, and appeared to be fatty. Estimations were made of the fat content of the dried liver of the control and cobalt group animals. These figures, together with the fresh weight of the livers of all the groups of animals, are given in table 4.

It will be noticed (column C, table 4) that compared with the body weight of the animals, the livers of the lambs of the control group were much heavier. In other words, cobalt deficiency seemed to have brought about a

TABLE 4. COMPARATIVE WEIGHTS AND FAT CONCENTRATION IN LIVER IN THE DIFFERENT GROUPS OF LAMBS

A		B	C[1]	D	E	F[2]
Group and type of data		Weight of liver	(See footnote)	Percentage fat in dried liver	Total fat in the whole liver	(See footnote)
		oz.		*percent*	gm.	
I. Control	Average	24.6	0.271	35.6	67.8	0.77
	Range	16.0–36.0	0.239–0.297	20.9–67.5	35.1–98.6	0.48–1.23
II. Cobalt sulphate (injected for 7 weeks)	Average	25.6	0.288			
	Range	22.0–31.0	0.250–0.350			
III. Cobalt sulphate (orally for 7 weeks)	Average	28.9	0.257			
	Range	22.0–34.0	0.237–0.276			
IV. Cobalt sulphate (orally for 17 weeks)	Average	21.8	0.202	24.6	44.9	0.41
	Range	19.0–24.0	0.185–0.223	21.0–27.2	39.9–52.1	0.39–0.47
V. Normal	Average	17.0	0.181			
	Range	12.0–20.0	0.170–0.208			

[1] $C = \frac{\text{Wt. of liver in oz.}}{\text{Body wt. in lb.}}$

[2] $F = \frac{\text{Total liver fat in gm.}}{\text{Body wt. in lb.}}$

hypertrophy of liver. Dietary therapy with 1 mg. of cobalt for 7 weeks had comparatively little effect in reducing the liver size, but treatment for 17 weeks brought considerable reduction in size, even though the livers were significantly heavier than those obtained from normal sheep of about the same age.

When the percentage of fat in the dried livers was examined (column D, table 4), it was found that so long as the animals were maintaining weight there was not a very significant difference between the control group and cobalt treated animals. Only the animals which were losing weight rapidly, yielded livers having a very high percentage of fat, viz., 54.0–67.5 percent.

When, however, the hypertrophied nature of the livers of the control group of lambs is taken into consideration, the total fat contents in the whole livers of animals in the two groups became widely divergent (column E, table 4). The differences between the two groups become greatly accentuated if the figures obtained by dividing the total liver fat content by the

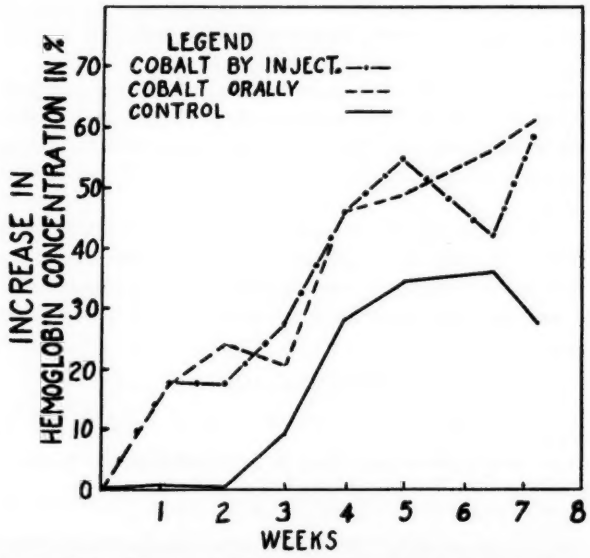

Figure 4. Rate of increase in hemoglobin concentration in percentage over the initial values in the various groups of the 2nd experiment.

body weight are examined (column F, table 4). These figures indicate a definite trend towards the production of fatty liver in cobalt deficiency. This fact is supported by histopathological observations, which are now being made. Fatty infiltration of the liver in cobalt deficient animals has also been observed by Bell (1937) and Wright (1941).

Summary

Cobalt salts administered by mouth at the rate of 1 mg. of the element per head per day brought about a rapid increase in the appetite and body weight of cobalt deficient sheep. By comparison, injection of cobalt salts gave a much slower response. Thiamin injections also brought about a definite improvement in rate of gain in body weight and appetite.

Anemia was found to be a concurrent feature in the deficient animals. Administration of cobalt brought about a slow and often erratic hemoglobin response. Injection of cobalt had no greater value in the stimulation of hemoglobin formation over oral administration. Thiamin treatment seemed to aggravate the anemia of the cobalt-deficient lambs.

The livers of the deficient lambs were hypertrophied and high in fat content. Administration of 1 mg. cobalt per day improved the condition of the organ but even after 17 weeks, the livers of the animals thus treated were significantly heavier than those of the normal animals.

The cobalt content of the livers of deficient animals was very low, but could be brought back to the normal level after treatment for 7 weeks with only 1 mg. of cobalt per day. The livers of the animals injected with similar doses of these cobalt salts, had about 10 times more cobalt than those of the latter group.

These data suggest that the physiological role of cobalt in sheep is probably indirect. The effect upon appetite seems to be direct, and that upon hemopoietic centers indirect. It is possible that the beneficial action of cobalt is linked with the normal production of the members of vitamin-B complex in the rumen.

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A STUDY OF COBALT DEFICIENCY IN NEW HAMPSHIRE WITH SHEEP[1]

H. A. KEENER, G. P. PERCIVAL AND K. S. MORROW[2]

New Hampshire Agricultural Experiment Station

A NUTRITIONAL deficiency which had affected the health of cattle in parts of New Hampshire for over a hundred years was reported by Keener, Percival and Morrow (1944) to be curable by cobalt feeding. This condition had been previously reported by Russel (1944) to affect various ruminants in other parts of the world including areas of Australia, New Zealand, Great Britain and Africa. On this continent it had been reported to affect cattle in Florida by Becker and Gaddum (1937) and Neal and Ahmann (1937) and in Michigan by Baltzer *et al.* (1941) and Duncan *et al.* (1943). Bowstead and Sackville (1939) and Bowstead *et al.* (1942) reported studies on a similar deficiency affecting sheep in Alberta, Canada. This deficiency has also been reported from Wisconsin by Geyer *et al.* (1945) as affecting dairy cattle and by Pope *et al.* (1946) and Winchester and Herrick (1946) as affecting sheep. The deficiency appears to exist also in other states along the eastern part of the United States.

Intensive field studies carried out by the authors to determine the extent of this deficiency in New Hampshire showed that it was troublesome in most areas of the state. In order to obtain conclusive proof of the existence of such a nutritional deficiency in New Hampshire and to learn more of its nature, it seemed necessary to study the deficiency under controlled conditions. The experiment reported here was carried out for that purpose.

Experimental Procedure

Ewe lambs were used as experimental subjects. This specie was selected because of its susceptibility to cobalt deficiency and because a large number of animals could be handled. Twenty lambs were purchased for the experiment consisting of 12 purebred Hampshires, 4 purebred Cheviots, 2 purebred Shropshires, and 2 high grade Shropshires. All the lambs were obtained from flocks where parasite treatments had been carried out and they appeared healthy in every respect. However, just before the experiment got under way, one Hampshire died, apparently from an abcess in the rumen wall. In order to prevent the possibility of the animals' consuming cobalt or any other chemical element that might be involved, no anthelmintic was

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given before or during the experiment. The lambs were paired as well as possible according to breed, size and origin so that one member of each pair could be fed cobalt and the other kept as a control.

Corn was fed as the sole concentrate because of its generally low cobalt content. The corn was purchased as corn meal on the local market and was fed at the rate of one pound per day per animal as long as it was cleaned up. The original lot of corn meal contained 0.11 p.p.m. of cobalt. Because of the scarce supply of corn during the period of the experiment, it was necessary to change to new lots of corn without further cobalt analyses being made. A protein supplement was not fed because of the higher cobalt content of this group of feeds.

Hay was fed to the experimental animals according to appetite. The hay used was secured from a farm in southeastern New Hampshire on which the deficiency had been cured in dairy cattle the previous winter by cobalt feeding. The hay consisted mainly of timothy, quack grass, red top and other grasses common to this area and was relatively free of legumes. The cobalt content averaged 0.06 p.p.m. A plain salt brick was attached to the wall of each pen. Water was kept before each animal in a glazed earthen crock.

As indicated previously, equalized feeding was not carried out in order that depressed appetite, one of the best symptoms of cobalt deficiency, might be indicated by feed consumption. The lambs were kept in individual pens which were fitted with a small box for the feeding of grain and a special hay manger which kept losses to a minimum. One member of each pair was fed a cobalt supplement. This supplement consisted of a solution of C.P. cobaltous sulfate which was fed as a drench twice per week so as to furnish the equivalent of 2 milligrams of cobalt per day. Since the pens were arranged in two rows with the cobalt animals (odd numbered) in one and the control animals (even numbered) in the other, any chance for mistake in cobalt feeding was practically eliminated.

Hemoglobin, packed red cell volume and red and white blood counts were determined periodically throughout the experiment on the blood of each animal. At the end of the experiment the blood serum of each animal was analyzed for cobalt. At the same time two pairs were slaughtered and their kidneys, livers and spleens were also analyzed for cobalt. The method of Ellis and Thompson (1945) was used for all of these determinations.

In addition to the above, weekly weights of each animal were obtained. A complete record was kept of the feed, water and salt consumption of each animal as well as any abnormality in condition or action. The weight of each fleece was recorded when the lambs were sheared at the end of the experiment.

The experimental animals were secured during the last part of November

and first part of December, 1945. After preliminary feeding on the experimental ration, but not including cobalt, the pairing was completed and the experiment got under way on December 31, 1945. The experiment continued until July 7, 1946, a period of 27 weeks.

Experimental Results and Discussion

Since the lambs used in this experiment were paired as well as possible according to breed, size and origin, most of the data are presented so as to compare the results obtained from the members of each pair. A summary of breed, feed consumption and change in body weight is given in table 1, while the weekly body weights and total feed consumption of each animal are presented graphically in figure 1.

The mean gain of the cobalt-supplemented animals was 16.3 pounds greater than that of the control animals, a difference which is significant at the 1 percent level. The mean total feed consumption of the cobalt supplemented animals was 44.7 pounds greater than that of the controls. This difference is also significant at the same level. The values given for total feed consumption are not intended as a measure of nutrient intake but as a measure of appetite. The mean difference in water consumption was 61 pounds in favor of the cobalt supplemented animals, which is significant at the 5 percent level. The mean difference in salt consumption was 0.4 pound in favor of the controls. This difference is not significant. It was influenced to a considerable extent by the heavy salt consumption of number 2, a control which exhibited moderate cobalt deficiency symptoms. This animal consumed rather large amounts of salt during several periods of the experiment.

It seems logical to assume that the greater gain in weight of those animals which received cobalt was due to a greater feed consumption. It would appear that the difference in feed consumption was due to an appetite depressing effect of a mild cobalt deficiency in the control group. However, it would be hazardous to say that there was any difference in feed utilization. Since there was a significant difference between the water consumption of the two groups, it might be logical to conclude that this was due to the difference in body weight of the animals of the two groups. However, it was noticed during this experiment, and during work with cattle, that animals suffering from severe cobalt deficiency invariably drank less water than normal animals maintained under similar conditions.

The visible effect of feeding supplemental cobalt to lambs in this experiment is plainly observed in figures 2 and 3. Most other pairs gave a similar comparison. These photographs simply show the greater size and condition which resulted from supplementing the low cobalt ration with cobalt.

Data from the blood studies are not given since significant differences

were not found between the cobalt supplemented animals and the controls. These results were complicated to some extent by the building up of the parasite infestation in certain sheep to the extent that anemia developed. This situation existed only during the last part of the experiment. However, in the case of the two pairs, numbers 1 and 2, and 11 and 12, where there was negligible internal parasite infestation, a considerable decrease in the red blood count was found in the two controls as the experiment progressed. There was also some decrease in the red blood count of the two cobalt

TABLE 1. SUMMARY OF INITIAL AND FINAL WEIGHTS, GAINS AND FEED, WATER AND SALT CONSUMPTION

Number	Group	Breed	Initial weight	Gain	Corn	Hay	Water	Salt
			lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1	Cobalt	Hampshire	113.0	27.0	188.5	273.3	1113	5.4
2	Control	Hampshire	108.5	−13.5	114.3	247.1	1037	10.0
3	Cobalt	Hampshire	90.0	17.0	188.5	249.7	1121	5.1
4	Control	Hampshire	92.5	13.5	189.0	182.0	921	4.2
5	Cobalt	Hampshire	83.0	29.0	189.0	266.7	1097	.7
6	Control	Hampshire	85.5	− 1.5	186.0	187.5	961	3.2
7	Cobalt	Hampshire	81.0	16.0	188.5	179.6	975	5.7
8	Control	Hampshire	82.0	11.0	185.0	190.3	971	5.4
9	Cobalt	Hampshire	71.0	31.0	187.5	250.1	1028	3.0
10	Control	Hampshire	73.0	8.0	188.5	210.0	982	3.5
11	Cobalt	Cheviot	53.0	34.0	177.0	161.9	690	2.5
12	Control	Cheviot	52.0	13.0	163.5	141.4	643	3.4
13	Cobalt	Cheviot	68.5	33.5	187.5	178.2	719	2.0
14	Control	Cheviot	69.0	19.0	179.5	204.9	760	.5
15	Cobalt	Shropshire	71.0	33.0	189.0	256.2	905	2.4
16	Control	Shropshire	65.5	21.5	186.5	212.0	881	.2
17	Cobalt	Shropshire	81.5	24.0	189.0	274.9	938	1.6
18	Control	Shropshire	79.0	27.5	187.5	218.5	882	2.0
20[1]	Control	Hampshire	90.0[2]	−20.0	22.3	75.2	191	
			70.0[3]	29.0	112.9	156.0	659	2.5
Average, cobalt lambs			79.1	27.2	187.2	232.3	954	3.2
Average, control lambs			78.6	10.9	175.5	199.3	893	3.6

[1] Not included in averages.
[2] 10 weeks no cobalt.
[3] 17 weeks cobalt.

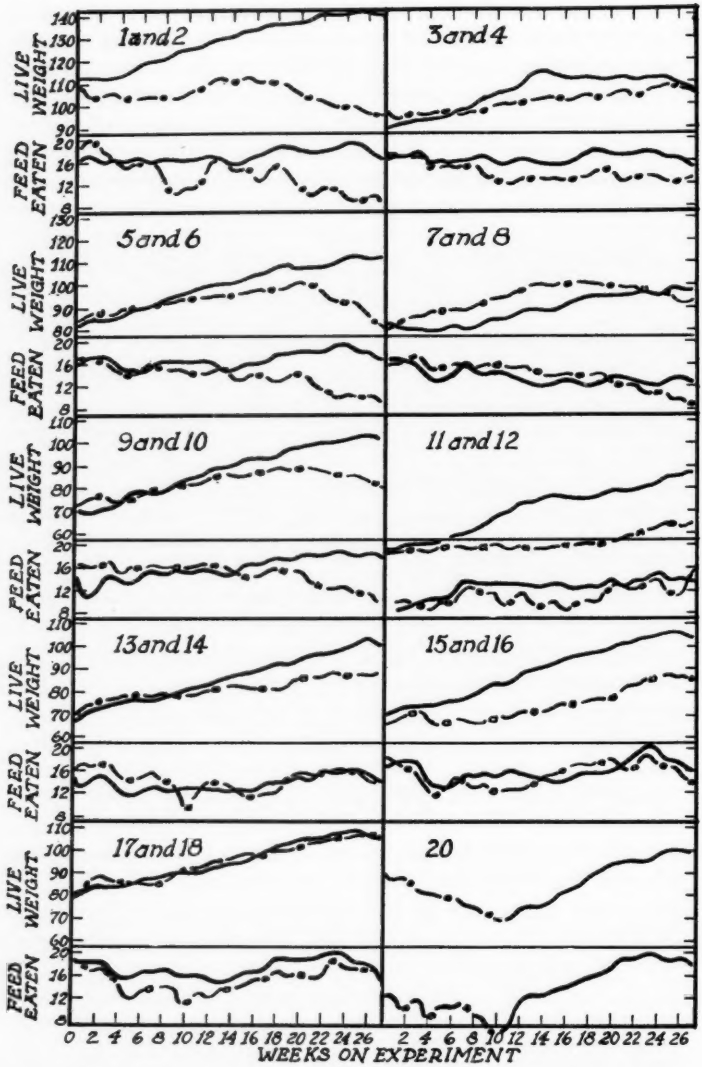

Figure 1. Weekly body weights and total weekly feed consumption (pounds) for individual animals throughout the experiment. Cobalt animals are shown by solid lines while controls are shown by broken lines.

animals, but not as much as with their controls. However, in the case of the packed red cell volume and hemoglobin in these two pairs, there was a gradual decline in all animals, but there was no apparent difference between the members of each pair. It should be noted that there was a close relationship between packed red cell volume and hemoglobin, but that the relationship between these two values and red blood count was not nearly as consistent. Other animals which showed negligible internal parasite infestation

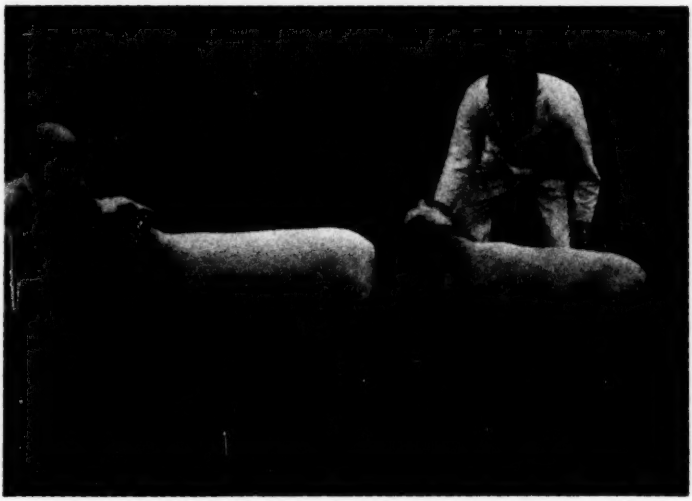

Figure 2. A comparison of cobalt lamb number 1 (left) and control lamb number 2 (right) at end of experiment.

were numbers 14, 16 and 18, all controls. None of these showed the extent of decrease in red blood count, packed red cell volume or hemoglobin that was found for numbers 2 and 12. This is in agreement with the fact that numbers 14, 16 and 18 did not exhibit definite cobalt deficiency symptoms as exhibited by number 12 and particularly number 2 although they were apparently affected.

Markedly low values for red blood count, packed red cell volume and hemoglobin were all found in animals that showed appreciable internal parasite infestation at the end of the experiment. This group includes numbers 3, 4, 5, 6, 7, 8, 9, 10, 13, 15, 17 and 20. It would thus seem that the red cell count, packed red cell volume and hemoglobin are not reliable criteria in detecting borderline cases of cobalt deficiency, at least in sheep. It is ap-

parent from these results that any appreciable internal parasite infestation could affect these values much more than a cobalt deficiency such as encountered during the experiment. However, the fact that severe cobalt deficiency does affect the blood picture was shown to some extent by numbers 2 and 12, but to a much greater extent by unreported work carried out by the authors on dairy cattle. In studying these data, it must be remembered

Figure 3. A comparison of cobalt lamb number 11 (left) and control lamb number 12 (right) at end of experiment.

that the cases of cobalt deficiency encountered during this experiment were almost all borderline cases, thus the marked effects reported by other investigators for this deficiency have not been observed to any appreciable extent during this experiment. However, it is probably the borderline case which does the greatest total damage to our livestock industry since it is so difficult to recognize that it goes unnoticed.

White cell counts were studied, but the only observation that can be made is that they tended to become lower as the red blood count, packed red cell volume and hemoglobin values decreased, but not nearly as rapidly. This was particularly true after these three values had been at a low point for a considerable period of time.

The effect of internal parasites on the gain in weight and well-being of the animals in the cobalt group as compared to the effect on animals in the

control group appears to have considerable practical significance. In the case of numbers 3 and 4 the gain of number 3 was higher than that of number 4 almost to the end of the experiment, although number 3 had been very anemic for a period of several weeks. Numbers 6, 8 and 10 showed much greater effects than their mates, who apparently had just as heavy infestations according to egg counts on the feces. Apparently neither numbers 13 nor 14 were affected appreciably although egg counts showed number 13 to have many more parasites than number 14. However, number 13 maintained a greater rate of gain than did number 14. Number 15 outgained number 16

TABLE 2. COBALT CONTENT OF BLOOD SERUM AT END OF EXPERIMENT

Cobalt lambs		Control lambs	
Number	Cobalt	Number	Cobalt
	γ/ml.		γ/ml.
1	.022	2	.0056
3	.082	4	.0018*
5	.0085	6	.0062
7	.060	8	.0042
9	.060	10	.0028
11	.017	12	.0020
13	.016	14	.0044
15	.025	16	.0040
17	.049	18	.0048
20	.052		
Average	.0392	Average	.00425

* Probably loss of sample during ashing. This value was ignored in determining average.

in spite of the fact that number 15 had considerable parasite infestation at the end of the experiment while that of number 16 was negligible. The gain in weight of number 17 would probably have been somewhat greater than that of number 18 had it not been for the development of a rather heavy infestation of parasites in number 17 near the end of the experiment. It was negligible in number 18.

Number 20 is a very interesting case in that she was the only animal on the experiment that showed severe cobalt deficiency symptoms. The condition of this control became so serious at the end of 10 weeks that it was feared that she might die. She was in such a condition that she ate practically no corn and less than half a normal amount of hay. She gnawed the board walls of the stall heavily. She was also very anemic. Four days after cobalt feeding was started her appetite had returned almost to normal and she started to gain back the weight that she had lost. This animal gained rather

steadily until near the end of the experiment in spite of the fact that a rather heavy parasite infestation was present. This was apparently the reason that the anemia remained.

The results of blood serum and tissue analysis are given in tables 2 and 3. These results show that those animals which received the equivalent of two milligrams of cobalt per day had several times as much cobalt in their blood and certain tissues as was present in their controls. These results would suggest the possibility of detecting a borderline cobalt deficiency by chemical analysis of blood or tissues. They also show that reserves of cobalt can be

TABLE 3. COBALT CONTENT OF SPLEEN, KIDNEY AND LIVER TISSUES AT END OF EXPERIMENT

Organ	Cobalt lambs		Control lambs	
	No. 1	No. 11	No. 2	No. 12
	γ/gm. dry wt.	γ/gm. dry wt.	γ/gm. dry wt.	γ/gm. dry wt.
Spleen	0.220	0.240	0.020	0.063
	0.094	0.240	0.024	0.024
Average	0.157	0.240	0.022	0.044
Kidney	1.470	1.250	0.115	0.058*
	1.680	1.340	0.109	0.069
Average	1.580	1.300	0.112	0.069
Liver	0.820	1.140	0.163	0.104*
	0.880	0.660	0.104*	0.133
Average	0.850	0.900	0.163	0.133

* Probable partial loss of sample during ashing due to swelling of tissue. These values were ignored in determining the averages.

built up in body tissues. These reserves may account for the fact that animals may appear normal for a period of several months after being placed on a low cobalt ration. The exceptionally high cobalt content of the kidneys of those animals receiving supplemental cobalt would seem to be due to the fact that since some of the cobalt is eliminated from the body by the action of the kidneys, the concentration is built up by this process.

Although fleeces from the cobalt animals averaged 9.1 pounds and the fleeces from the controls averaged 8.5 pounds, this difference was not significant. However, a general superiority was observed in the fleeces from the cobalt animals, apparently reflecting a generally better state of health.

Summary

A paired experiment was carried out with lambs in an attempt to substantiate field studies which indicated a widespread cobalt deficiency in New Hampshire. Although, with very few exceptions, only borderline deficiency cases were encountered, the average gain in weight of the animals receiving cobalt was approximately two and a half times that of the controls. Differences in gain in weight appeared to be due to differences in feed consumption. Although blood counts were not found to be reliable for detecting borderline cases of this deficiency, analysis of blood serum and certain tissues for cobalt did appear to have potential value for this purpose.

It is concluded that cobalt deficiency can result from feeding low cobalt hay such as found in New Hampshire and that the effects of even a borderline deficiency are of considerable importance.

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FURTHER COMPARISONS OF THE UTILIZATION OF NITROGEN OF UREA WITH THAT OF SOME FEED PROTEINS BY SHEEP[1]

TOM S. HAMILTON, WILLARD B. ROBINSON,[2]
AND B. CONNOR JOHNSON
University of Illinois[3]

CONTINUING this study, reported in part by Johnson, Hamilton, Mitchell, and Robinson (1942) and by Johnson, Hamilton, Robinson and Garey (1944), additional data have been obtained on the relative availability to sheep of the nitrogen in urea-containing rations and in rations, the protein of which was preformed, and from various feed sources. This paper will report the results of nitrogen balance experiments designed to compare the utilization of the nitrogen in urea, dried skimmilk, gluten feed, dried skimmilk plus cystine, linseed meal, casein, casein plus cystine, and urea plus cystine. As in our previous tests, growing native wether lambs were used as experimental animals.

Experimental Methods

As in the past, six native grade wether lambs were paired in each test three on one ration and three on another; then the rations were reversed and a subsequent test run. In this manner eight sets of rations were compared Thus, in most cases, it was possible to compare not only the results obtained between individuals in a pair of lambs, but also the results obtained on the same lamb eating the two different rations in adjacent periods. The lambs weighed from 50 to 60 pounds initially. The nitrogen balance method, as previously described by Harris and Mitchell (1941) and by Johnson *et al.* (1942), was used as a measure of the nitrogen utilization. As in the past, the collection periods were of 9 or 10 days duration, preceded by preliminary periods of 6 or 7 days during which the lambs received the same respective rations. Both animals in each pair received daily isocaloric amounts within narrow limits. During the first four tests (periods 14 to 21, inclusive), the basal ration consisted of timothy hay 47.65, corn molasses 20, corn 30, bonemeal 1, salt 1, cod-liver oil 0.25, and sodium sulfate 0.10 and contained 6.45 percent crude protein. The last four tests (periods 22 to 29) were conducted with a basal ration furnishing about 2.5 percent protein and consisted of timothy hay 20, wood flock 16.20, corn 13.50, starch 16.50, molasses 30,

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[2] Present address: New York State Agricultural Experiment Station, Geneva, New York.

[3] Animal Nutrition Division, Urbana, Illinois.

soybean oil 1.30, bonemeal 1, salt 1, cod-liver oil 0.25, sodium sulfate 0.24 and ferric oxide 0.01.

The biological values of the nitrogen in the various rations were calculated in the usual way, using 5.563 mgm. of metabolic nitrogen in the feces per gram of dry matter consumed and 1.252 gm. of endogenous nitrogen in the urine per 100 pounds live weight of the lamb. These factors were obtained on the lambs used in the experiments reported here.

Where the data have been treated statistically, Student's (1908, 1925) method of analyzing paired data was used. A P value of 0.03 or less is considered significant.

Experimental Results

In the table are tabulated the essential data relative to the eight comparisons, involving sixteen separate tests.

The first comparison (periods 14 and 15) was between rations containing 11.6 and 17.0 percent crude protein (T.N.×6.25), respectively. Urea furnished 46.0 percent of the total nitrogen in the former ration, while it furnished 63.0 percent in the latter. Using the nitrogen balance, expressed as a percent of the nitrogen absorbed, as a measure of the efficiency with which the total nitrogen of the two rations was utilized, no differences were observed, the percentages of the absorbed nitrogen retained being 12.99 for the 11.6 ration and 12.40 for the 17.0 percent ration. These figures are in agreement with those previously reported by Johnson *et al.* (1942) who showed that, to a basal ration furnishing about 6 percent preformed protein, the addition of urea increased the biological utilization of the total nitrogen of the ration up to, but not above, the equivalent of about 12 percent crude protein. The significantly reduced biological value of the nitrogen in the 17.0 percent ration, as compared with that for the 11.6 percent ration, is to be expected if the preceding statement is correct. Harris and Mitchell (1941) reported that, with successive additions of urea to a basal ration containing about 5 percent preformed protein, to produce rations containing about 8, 11, and 15 percent protein equivalent, the average biological values were 74, 60, and 44, respectively.

In the next six comparisons (periods 16 to 25, inclusive), an attampt was made to determine whether the quality of protein in rations, containing the equivalent of about 12 percent crude protein or less, affected its utilization by sheep. Results previously reported from this laboratory (Johnson *et al.*, 1942) indicated that, when the nitrogen requirements of lambs exceeded that furnished by a 12 percent protein ration, additional nitrogen supplied by preformed protein was more efficiently utilized than was the additional nitrogen supplied by urea. In the first three of these six comparisons, urea

DIGESTIBILITY, NITROGEN BALANCE, AND BIOLOGICAL VALUE OF THE NITROGEN IN UREA-CONTAINING AND NON-UREA-CONTAINING RATIONS FED TO GROWING LAMBS

Periods No.	Rations compared	No. of comparisons	Crude protein[1] in ration	Nitrogen intake			Apparent digestibility of N	Nitrogen balance as percent of N absorbed	Difference	Significance of difference	Biological value	Difference	Significance of difference
				Total	Urea N	Non-urea supplement N							
			pct.	*gm.*	*pct.*	*pct.*	*pct.*	*pct.*		*P value*	*pct.*		*P value*
14, 15	Urea	9	11.62	11.424	46.0	0	63.9	12.99	0.59	0.33	47.6	11.8	<.00001
	Urea		17.03	16.226	63.0	0	75.3	12.40			35.8		
16, 17	Urea	10	13.74	13.635	42.7	0	67.4	19.15			48.8		
	Dried skimmilk		11.65	11.616	0	66.3	65.7	21.32	2.16	0.10	52.3	3.5	0.23
18, 19	Urea	12	11.79	11.698	47.5	0	58.7	25.34			58.8		
	Gluten feed		11.68	11.762	0	73.0	53.0	29.42	4.08	0.17	63.8	5.0	0.13
20, 21	Urea	12	9.64	9.007	37.1	0	56.4	28.80			66.9	2.5	0.24
	Dried skimmilk and cystine		10.27	9.696	0	38.4	53.1	31.52	2.64	0.4	64.4		
22, 23	Urea	12	11.82	9.894	74.8	0	66.0	20.10			52.7		
	Linseed oil meal		11.59	9.655	0	74.2	60.0	29.60	9.50	0.005	62.6	9.6	0.006
24, 26	Urea	12	11.66	11.597	71.7	0	61.8	8.96			48.6	0.6	0.26
	Casein		12.12	11.460	0	74.5	65.7	12.63	3.67	0.07	48.0		
25	Casein	3	12.79	11.460	0	74.5	66.0	11.49			45.8		
	Casein and cystine		12.70	11.705	0	75.0	67.6	24.73	13.24	0.09	54.5	8.7	0.08
27, 28, 29	Urea	15	10.51	11.399	84.1	0	68.8	9.78			45.1	1.7	0.29
	Urea and cystine		10.51	11.399	82.1	2.0	67.7	11.22	1.44	0.31	43.4		

[1] T.N. ×6.25.

furnished between 37.1 and 47.5 percent of the total nitrogen in the urea ration, while in the non-urea rations a protein concentrate supplied between 38.4 and 73.0 percent of the total nitrogen. The total nitrogen in the two rations being compared was approximately equal and both were equivalent to about 12 percent or less crude protein.

The first comparison of this nature was between a ration in which urea furnished 42.7 percent of the total nitrogen and one in which dried skimmilk supplied 66.3 percent of the total nitrogen. For the urea ration and for the non-urea ration, the apparent digestibilities of the nitrogen were 67.4 and 65.7 percent, respectively, and the nitrogen balances, expressed as a percent of the nitrogen apparently absorbed, were 19.15 and 21.32, respectively neither difference between averages being significant. The estimated biological values, for the urea and non-urea rations, were 48.8 and 52.3, respectively; the difference of 3.5 in favor of the skimmilk ration was not significant ($P = .23$).

In the next comparison (periods 18 and 19) both rations again contained nitrogen equivalent to about 12 percent crude protein, urea furnishing 47.5 percent of the total nitrogen in one ration and corn gluten feed supplying 73.0 percent of the total nitrogen in the other. For the urea and the gluten feed rations the average respective digestibilities were 58.7 and 53.0; the nitrogen balances were 25.34 and 29.42; and the estimated biological values were 58.8 and 63.8. None of these differences were statistically significant.

Although it is well known that the proteins of skimmilk powder are of very good quality for the rat, provided that the powder has not been heated to a too high temperature, it has been shown by Mitchell and Beadles (1930) and by Fairbanks and Mitchell (1935) that cystine is the limiting amino acid in the utilization of the proteins of skimmilk powders. In the next test (periods 20 and 21) a urea-containing ration was compared with one in which cystine-supplemented dry skimmilk supplied 38.4 percent of the total nitrogen. In this ration cystine was added to the extent of three percent of the protein in the skimmilk powder. In the urea ration, urea furnished 37.1 percent of the total nitrogen. Judging from the respective apparent digestibilities, percentages of nitrogen absorbed, and the biological values, this cystine-fortified skimmilk ration was no better than the urea ration. The crude protein equivalent in these rations had been reduced to about 10 percent so that the supplementing effect should have been more definitely observed had there been a supplementing effect. Since no benefits were obtained by cystine supplementation of the skimmilk ration, these observations may be taken as confirmatory evidence in support of the idea, previously suggested by Johnson *et al.* (1942) and Johnson *et al.* (1944), that up to the maximum amount of nitrogen required by the microorganisms in the

paunch of ruminants (this is equivalent to about 11–12 percent crude protein for growing lambs), practically all of the food nitrogen is utilized first by the microorganisms of the paunch. The host later is benefited by the digestion of these microorganisms passing down the digestive tract.

The data reported so far in this as well as previous studies from this laboratory have indicated that, provided the total nitrogen of the ration did not exceed about 11 or 12 percent protein equivalent and provided further that urea did not provide more than about 50 percent of the total nitrogen, growing lambs could utilize urea nitrogen as efficiently as preformed protein and that the preformed protein failed to exhibit any difference in biological value.

In the next two comparisons the proportion of nitrogen in the urea rations supplied by urea was increased, although the total protein equivalent of the rations was maintained at about 12 percent. This was accomplished by reducing the timothy hay, which at a level of about 45 percent had been supplying nearly 50 percent of the nitrogen in the basal rations, to 20 percent of the basal ration. In periods 22 and 23, a urea ration in which 74.8 percent of the total nitrogen was furnished by urea was compared with a linseed oil meal ration in which linseed oil meal supplied 74.2 percent. Although the average apparent digestibility of the nitrogen in the urea ration was 66.0 and that for the linseed oil meal ration was 60.0, the difference was not statistically significant. However, both the nitrogen balance and biological value data show a definite superiority of the linseed oil meal ration over the urea ration. For the urea and linseed oil meal rations the nitrogen balance, expressed as a percent of the nitrogen apparently absorbed, was 20.10 and 29.60, respectively, and the estimated biological values were 52.7 and 62.6, respectively. The probability that these differences were fortuitous was .005 and .006 for the nitrogen balance and biological value averages, respectively.

In all of the remaining tests to be described (periods 24–29) the low nitrogen basal ration (the same that was used in the linseed meal test) was used. This basal ration supplied but about 25 percent of the total nitrogen of the ration, whereas in the first four tests, the basal ration supplied about 50 percent. The next test (periods 24 and 26) was comparable to the previous one except that casein nitrogen instead of linseed meal nitrogen was compared with urea nitrogen. In this test, the average apparent digestion coefficients for the nitrogen in the urea ration was 61.8, while that in the casein ration was 65.7. The nitrogen balance, expressed as a percent of the nitrogen absorbed, was low for both rations. That for the urea ration was 8.96 and for the casein ration 12.63. The calculated biological value was for the urea

ration 48.6, and that for the casein ration, 48.0. None of these differences were significant.

In period 25, the low timothy hay basal ration was supplemented with casein for half of the sheep, while their pair-mates received the same ration plus 0.3 percent cystine. Urea was not used in this test and the supplements furnished about 75 percent of the total nitrogen of the ration. This test was of a preliminary nature and was planned for the purpose of obtaining evidence whether or not cystine supplemented casein when fed to sheep as it does when fed to rats.

Only three pairs of sheep were used and no reversal was made. Sodium sulfate was included in the rations as usual. Average figures indicated that, compared with those of the non-cystine-supplemented ration, the total nitrogen of the cystine-supplemented ration was digested better by 1.6 percent, that 13.24 percent more nitrogen was retained, and that the biological value was 8.7 percent higher. While these data are indicative that, under these conditions, cystine may supplement the proteins present, they are insufficient to warrant a positive conclusion.

Eleven to twelve percent protein equivalent in rations for growing lambs seems to be critical in that this concentration of nitrogen represents about the maximum which the microorganisms of the paunch can use. Above this concentration, food protein apparently exhibits a biological value approaching that observed in non-ruminants. This was shown in periods 20 and 21, in which 0.3 percent cystine added to a dried skimmilk ration containing 9–10 percent protein failed to increase the utilization of nitrogen over that of a urea-containing ration; and by the last test, periods 27, 28, 29, in which 0.3 percent cystine added to a 10.5 percent protein equivalent ration failed to increase the nitrogen utilization. In the latter test, urea furnished 82–84 percent of the nitrogen of the rations.

Except for the linseed oil meal test (periods 22–23) all data obtained in this year's work are in agreement with our previous findings which indicated that, up to a level of 11–12 percent protein equivalent in a ration for growing lambs, practically all of the nitrogen consumed is used by the microorganisms of the paunch for the synthesis of their own cellular proteins, and that preformed food proteins show no appreciable differences in biological value. Above about 12 percent protein, and below the minimum required for maximum growth, preformed food proteins may exhibit biological values approaching those observed when fed to non-ruminants.

The data reported here are in agreement with those previously reported from this laboratory (Johnson *et al.*, 1942). Whether or not the conclusions just stated are supported by the data of Loosli and Harris (1945) is difficult

to ascertain from their published report. Their animals and rations were quite comparable to ours and a nitrogen balance technic was used. They reported both higher absolute amounts of nitrogen retained and higher percentages of absorbed nitrogen retained on 10 percent protein rations containing urea plus methionine or linseed meal than on urea. However, these results could readily be accounted for if the lambs ate more of the two rations which induced the greater balance. Insufficient data were reported in order to settle this point.

The higher utilization of linseed meal nitrogen over urea nitrogen, when both were added to a low nitrogen basal ration, is not readily explained on the above hypothesis.

Perhaps the most plausible explanation of the findings, in periods 22 and 23, that the nitrogen of the linseed meal ration was more efficiently utilized than was the nitrogen of the ration containing a comparable amount of nitrogen from urea, is that the smaller concentration of preformed protein in the basal ration (about 25 percent of the total nitrogen as compared with about 50 for previous tests) failed to supply sufficient amounts of certain amino acids essential for rapid growth of the microorganisms in the paunch. If this were the explanation, however, the casein supplemented basal ration (periods 24 and 26) should have proved even better than the linseed meal supplemented basal ration (periods 22 and 23), provided, of course, that the casein was the better protein as is usually assumed.

Another possible explanation for the apparently better utilization of the nitrogen of linseed meal over that in urea of periods 22 and 23 would be that the protein molecules in linseed meal are more resistant to the degradation actions of the paunch microorganisms than are those of some other proteins. This would be comparable to the more resistant nature of raw soybean proteins, over heated soybean meal proteins, to the action of the digestive enzymes in non-ruminants. While numerous feeding trials with beef cattle have indicated a superiority of linseed meal over cottonseed meal as a protein supplement, Morrison (1937) and Willman, Morrison, and Klosterman (1944) reported that the nitrogen of linseed meal was greatly superior to that of urea in fattening lambs, more rigidly controlled tests have generally failed to show any superiority of linseed meal proteins over the proteins of other commonly used plant protein supplements. Bethke *et al.* (1928) reported equal value of the proteins of linseed meal and of cottonseed meal to all classes of animals, except for growing chicks cottonseed meal was superior to linseed meal. Miller, Morrison, and Maynard (1937) showed that the proteins of linseed meal and of soybean oil meal were of equal value as a protein supplement for growing lambs. Also, for milk production in dairy cows, Rupel, Bohstedt, and Hart (1943) reported that the nitrogen of linseed

meal was no better than that of urea when both were used as a protein supplement; and Loosli and Harris (1945) showed, with growing lambs, that the nitrogen of linseed meal and that of urea plus methionine were of equal value when measured by gains of lambs, digestibility, nitrogen balance, or as percent of nitrogen retained.

Thus, the literature furnishes both confirmatory and non-confirmatory evidence for the superiority of linseed meal nitrogen.

Summary and Conclusions

Further experiments on the comparative utilization of the nitrogen of urea and that of some feed proteins are reported. Growing lambs were used as experimental animals and the paired-feeding procedure, with single reversal of rations, was used throughout. Nitrogen balance was the criterion. Eight different comparisons were studied with the following results:

1. The nitrogen in a ration containing 16.2 percent protein equivalent (63 percent from urea) was less efficiently utilized than that in a ration containing 11.4 percent (46 percent from urea).

2. In confirmation of our previously reported data, the nitrogen of urea was as well utilized by growing lambs as were the same amounts of nitrogen from dried skimmilk, dried skimmilk plus cystine, glutenfeed, casein or casein plus cystine, provided the protein equivalent in the rations does not exceed about 12 percent and provided at least 16 percent of the total nitrogen is in the form of preformed protein.

3. The nitrogen of linseed oil meal was more efficiently utilized than that of urea when the rations contained about 12 percent protein equivalent of which one-fourth was supplied by a basal ration containing preformed proteins.

It is concluded that urea is as satisfactory a source of nitrogen for growing lambs as that from most ordinary feeds, provided at least 25 percent of the food nitrogen is in the form of preformed protein and provided further that the total protein equivalent of the ration does not exceed about 12 percent. The nitrogen of linseed oil meal seems to be an exception in that it is more efficiently utilized than that of urea.

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UREA AS AN EXTENDER OF PROTEIN WHEN FED TO LAMBS[1]

H. M. Briggs, W. D. Gallup, V. G. Heller and A. E. Darlow
Oklahoma Agricultural Experiment Station[2]

UREA has been used to replace vegetable protein in experimental rations for cattle and sheep at the Oklahoma Station. The performance of urea as an extender of protein in the cattle rations has been presented in a paper by Briggs *et al.* (1947). The literature was reviewed in that paper and information was presented on the metabolism of the nitrogen in urea and its value in the fattening and wintering of cattle. This paper reports metabolism experiments conducted with lambs fed rations similar to those reported in the experiments with steers.

Method of Procedure

Cottonseed meal, crystalline urea, DuPont's "Two-Sixty-Two" feed compound and pelleted feeds containing urea were used as sources of nitrogen in the lamb rations (Briggs *et al.*, 1947).

Eight lambs were used in each digestion trial. Collections were made in false bottom cages with the feces being retained on a screen while the urine was caught below in a glass container. Daily feces collections were dried twenty-four hours in an electric oven, stored in an airtight container, and were weighed and sampled at the close of the collection period. Urine was collected daily, stored in a jar containing H_2SO_4 and thymol, measured to the nearest ml. and sampled. The lambs were fed and watered twice daily during ten-day preliminary feeding periods and ten-day collection periods; half of the lambs were on collection while the others were receiving preliminary rations. 7.5 gms. of granulated salt was added to each feed. The nitrogen supplements were fed in amounts calculated to provide rations of equal nitrogen content. The small amounts of refused feed were analyzed and subtracted from that fed to determine dry matter and nutrient intakes. Usual ether extraction procedures were followed in making chemical analyses although it is realized urea is partially soluble in ether.

Experimental Results and Discussion

In the first metabolism experiment, which consisted of five digestion and nitrogen balance trials, a comparison was made between different preparations of urea and cottonseed meal as sources of nitrogen to supplement prairie hay. The lambs were grade Rambouillet wethers of Texas origin and aver-

[1] A research grant from the E. I. du Pont de Nemours and Company, Inc., has assisted in making this study possible.
[2] Departments of Animal Husbandry and Agricultural Chemistry Research, Stillwater, Oklahoma.

aged about 66 pounds in weight. During the first trial the lambs were fed prairie hay alone at the rate of 700 gms. per day; during the remaining trials they received, in addition to the same feeding of hay, one of the nitrogen supplements shown in table 1. The supplements were fed in the following order: urea pellets No. 4 (a pelleted urea feed), crystalline urea, cottonseed meal, and Du Pont's "Two-Sixty-Two." The daily allowance and composition of feeds are given in table 1.

TABLE 1. DAILY AMOUNT AND CHEMICAL COMPOSITION OF HAY AND SUPPLEMENTS OFFERED WETHER LAMBS IN THE FIRST METABOLISM STUDY

Feed	Daily allowance	Dry matter	Percentage composition of dry matter				
			Protein (N×6.25)	Ether extract	Crude fiber	Nitrogen-free extract	Organic matter
	gms.	*percent*					
Prairie hay	700.0	90.2	3.12	2.34	32.26	55.68	93.45
Cottonseed meal	103.7	91.5	45.04	7.76	10.15	30.97	93.92
Urea pellet No. 4[1]	101.2	89.3	48.77	7.05	3.97	36.47	96.26
DuPont "Two-Sixty-Two"[2]	16.2	100.0	263.10	—	—	—	97.80
Crystalline urea	15.0	100.0	283.40	—	—	—	—

[1] Practically all the nitrogen in urea pellet No. 4 was provided by urea. The pellets were composed of hominy feed with 10 percent of blackstrap molasses and sufficient urea to give a total crude protein equivalent of 43.5 percent on an air-dry basis. They were manufactured through the courtesy of Nutrena Mills, Inc.

[2] DuPonts "Two-Sixty-Two" is a commercial preparation of urea with small amounts of conditioning agents added to improve mixing qualities. This product and the crystalline urea were obtained through the courtesy of du Pont de Nemours and Company, Inc.

The average protein content (N×6.25) of the dry matter eaten by the lambs receiving the supplemental feeds varied from 8.3 to 8.7 percent. There were no feed refusals. Data obtained in this experiment are shown in table 2.

In the second metabolism experiment, conducted with eight grade Rambouillet lambs that averaged about 56 pounds in weight, cottonseed meal was compared with pelleted protein supplements containing increasing amounts of urea. These pelleted supplements, referred to in the text and tables as urea pellet No. 1, 2, and 3, supplied urea nitrogen at levels of approximately 25, 50 and 75 percent, respectively, of the total supplemental nitrogen. The remainder of the nitrogen in the pellets came from cottonseed meal, hominy feed and molasses.

Each pellet contained 10 percent blackstrap molasses and, in addition, pellet No. 1 contained 4 percent DuPont "Two-Sixty-Two" feed compound, 75 percent cottonseed meal and 11 percent hominy feed. Pellet No. 2 carried 8 percent "Two-Sixty-Two," 50 percent cottonseed meal, and 32

TABLE 2. AVERAGE APPARENT DIGESTIBILITY OF NUTRIENTS AND AMOUNT OF NITROGEN STORED BY LAMBS RECEIVING RATIONS OF PRAIRIE HAY AND DIFFERENT NITROGEN SUPPLEMENTS IN THE FIRST METABOLISM STUDY

Supplements fed with prairie hay	Apparent digestibility of nutrients in ration					Daily nitrogen intake	Daily nitrogen storage
	Protein (N×6.25)	Ether extract	Crude fiber	N-free extract	Organic matter		
	percent	*percent*	*percent*	*percent*	*percent*	*gm.*	*gm.*
None	−6.0	23.7	45.5	46.4	43.8	3.2	−1.9
Cottonseed meal	55.8	55.3	56.2	56.0	56.0	10.6	2.1
Urea pellets No. 4	60.0	49.2	52.4	53.2	53.5	11.1	1.2
DuPont "Two-Sixty-Two"	64.3	43.3	57.8	52.7	51.4	10.0	0.3
Crystalline urea	62.8	36.4	55.0	55.0	51.9	10.0	0.1
Difference[1] in mean required for 5% point	4.4	4.5	3.8	2.9	2.2	—	0.7
1% point	5.9	6.0	5.1	3.8	3.0	—	0.9

[1] Calculated from the analysis of variance method (Snedecor, 1938).

percent hominy feed, while pellet No. 3 carried 12 percent, 25 percent and 53 percent, respectively of these components. The composition and daily allowance of feeds used in this experiment are given in table 3.

The basal ration of prairie hay was fed to two groups of 4 lambs each in the first digestion trial; in subsequent trials the 4 supplemented rations were fed to the 8 lambs in rotation so that each lamb received a different ration during any one collection period. All lambs refused some unsupplemented hay and a few refused small amounts of hay when supplements were fed. There were no refusals of supplement. The average protein content of the

TABLE 3. DAILY AMOUNT AND CHEMICAL COMPOSITION OF HAY AND SUPPLEMENTS OFFERED WETHER LAMBS IN THE SECOND METABOLISM STUDY

Feeds[1]	Daily allowance	Dry matter	Percentage composition of dry matter				
			Protein (N×6.25)	Ether extract	Crude fiber	N-free extract	Organic matter
	gms.	*percent*					
Prairie hay	600	91.0	3.54	1.76	34.62	53.14	93.06
Cottonseed meal	176	91.6	43.80	6.68	10.17	32.97	93.62
Urea pellet, No. 1	164	89.6	46.60	6.65	8.94	30.51	92.70
Urea pellet, No. 2	146	89.0	50.58	7.05	7.37	28.67	93.67
Urea pellet, No. 3	152	88.7	49.14	7.37	5.25	33.21	94.97

[1] The urea pellets were manufactured through the courtesy of Nutrena Mills, Inc.

dry matter consumed by the lambs when the supplements were added varied from 12.65 to 13.11 percent. The data secured in the second experiment are shown in table 4.

TABLE 4. AVERAGE APPARENT DIGESTIBILITY OF NUTRIENTS AND AMOUNT OF NITROGEN STORED BY LAMBS RECEIVING RATIONS OF PRAIRIE HAY AND DIFFERENT NITROGEN SUPPLEMENTS IN THE SECOND METABOLISM STUDY

Supplement[1] fed with prairie hay	Apparent digestibility of nutrients in ration					Daily nitrogen intake	Daily nitrogen storage
	Protein (N×6.25)	Ether extract	Crude fiber	N-free extract	Organic matter		
	percent	*percent*	*percent*	*percent*	*percent*	*gm.*	*gm.*
None	1.3	30.2	46.4	39.0	40.2	2.6	−1.1
Cottonseed meal	59.3	66.3	51.8	58.1	54.8	14.4	3.5
Urea pellet, No. 1	63.0	61.2	50.8	51.2	53.0	14.0	3.0
Urea pellet, No. 2	63.0	61.1	50.3	52.2	53.3	13.5	2.2
Urea pellet, No. 3	66.2	60.3	47.6	53.8	54.0	13.7	1.9
Differences in mean required for: 1% point	4.8	4.9	7.3	5.3	2.9	—	.8
5% point	6.5	6.5	9.7	7.1	3.9	—	1.0

[1] The urea pellets were manufactured through the courtesy of Nutrena Mills, Inc.

Discussion of Results

The lambs consumed their total allowance of feed during all trials in the first experiment. Consequently, no effect of the supplements on appetite was noted. However, in the second experiment the lambs refused an average of 98 grams of the hay daily when it was unsupplemented; the refusal of hay amounted to an average of only 2.4 grams when cottonseed meal was fed as the supplement, 5.8 grams when urea pellet No. 1 was fed, 18.2 grams when pellet No. 2 was fed, and 6.2 grams when pellet No. 3 was fed. These refusals, although related to appetite and generally indicative of the nutritive value of rations, are recognized as disturbing factors in a study of nutrient digestibility.

In both the first and second metabolism experiments differences in digestibility between corresponding nutrients in the unsupplemented and supplemented rations were highly significant. These differences favored the supplemented rations. Likewise, there were similar significant differences among the supplemented rations in the first experiment, the highest digestion coefficients for nutrients other than protein (N×6.25) usually being obtained with the cottonseed meal ration.

In the first experiment, a supplement of urea, hominy feed and molasses

(pellet No. 4) improved the prairie hay ration but failed to give as good results as cottonseed meal as measured by differences in nutrient digestibility and storage of nitrogen. Direct evidence that urea nitrogen improved the basal ration was obtained when DuPont's "Two-Sixty-Two" and crystalline urea were fed as the only supplements. When these supplements were fed, there was a significant increase in the digestibility of all nutrients in the hay. Since these results in some respects are contradictory to those obtained in experiments with steers (Briggs *et al.*, 1947), further work with other feed combinations and urea seems warranted.

In the second metabolism experiment when pelleted feeds were compared with cottonseed meal, differences among the supplemented rations in nutrient digestibility were usually too small to be of statistical significance. Such differences as were found in the digestibility of nutrients other than protein can not be ascribed entirely to differences in urea content of the supplements.

Although urea nitrogen was highly digestible as measured by its disappearance from the digestive tract, lambs were apparently not highly efficient in its utilization. There was little storage of nitrogen when crystalline urea was fed in the first study, and in the second study there was a uniform decrease in storage as the urea content of the pelleted feeds was increased. Pellet No. 1, which contained the smallest proportion of urea, permitted nitrogen storage about equal to that of cottonseed meal. Indirect calculations of the data in table 4 indicate that even though the lamb is not as efficient in the use of nitrogen from urea as that from cottonseed meal, some utilization is made of the urea nitrogen. If the urea nitrogen was not used to some extent the lambs would have had to be extremely efficient in the utilization of the nitrogen in natural feed stuffs to have obtained a positive nitrogen balance of 1.9 gms. daily when urea pellet No. 3 was used as the supplement.

The rations supplemented with crystalline urea and DuPont's "Two-Sixty-Two" feed compound provided less energy intake than the ration supplemented with cottonseed meal. This may in part explain the decreased nitrogen storage in those rations with the lower energy intake. Further work is needed to determine how much of this increased storage is due to energy intake and how much is the result of improved protein metabolism from the addition of another source of protein. Loosli and Harris (1945) added methionine to a lamb ration in which urea was used as a source of supplementary nitrogen and found significant improvement in the retention of the urea nitrogen. The nitrogen retention of a urea and methionine supplemented ration was similar to that of a ration in which the same amount of dietary nitrogen was supplied by linseed meal. An addition of sodium sulphate to a urea containing ration did not improve the utilization of the urea nitrogen.

Summary

Cottonseed meal, crystalline urea, DuPont's "Two-Sixty-Two" feed compound and pelleted concentrate feeds containing approximately 4, 8 and 12 percent of urea were fed as sources of supplemental nitrogen for lambs during digestion and nitrogen balance trials. The addition of urea alone and as "Two-Sixty-Two" to a basal ration of low-protein prairie hay increased the apparent digestibility of hay nutrients and changed nitrogen balances from slightly negative values to slightly positive values. Pelleted feeds with 25 percent of their total nitrogen supplied by 4 percent of urea permitted about the same storage of nitrogen as cottonseed meal. Nitrogen storage decreased as the proportion of total nitrogen supplied by urea was increased in the pellets to 50 and 75 percent.

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REACTIONS OF SOUTHDOWN SHEEP TO TWO ENVIRONMENTS

RALPH W. PHILLIPS[1] AND DAMON A. SPENCER
United States Department of Agriculture

IT IS generally recognized that the development and performance of an animal are dependent upon both its genetic makeup and its environment. The relative importance of these two factors obviously varies with the conditions under which animals are raised and maintained, the degree of genetic homogeneity of the animals involved, and the genetic adaptability of the animals to the environment to which they are exposed. Some attention has been given to the breeding of animals adapted to different environmental conditions. This is well illustrated in a practical way by the stratification of the sheep industry in Great Britain (White, 1944; Dinsdale, 1944; Bywater, 1944; Thomas, 1944; Seward, 1945). Another illustration may be found in recent work on development of beef cattle adapted to subtropical conditions through the use of a combination of European and zebu cattle blood (Rhoad and Black, 1943; Rhoad, Phillips and Dawson, 1945; Phillips, 1946). Still another example is the development of Columbia sheep (Spencer and Stoehr, 1941) from a crossbred foundation, thus producing an animal that could make more effective use than the Rambouillet of the more productive range lands in the western portion of the United States. However, relatively little work has been done in this field and even less has been done on the reactions of livestock to what may appear to be rather unimportant differences or changes in environment. The object of this paper is to report results of such a study with Southdown sheep.

Material and Methods

The Bureau of Animal Industry had maintained a flock of Southdown sheep at Beltsville, Maryland, for many years. These sheep received excellent care. During the summer they were kept on temporary pastures and were rotated at frequent intervals to ensure fresh feed and to keep parasite infestation at a minimum. During the winter they received good quality hay and sufficient grain to keep them in excellent condition. It became desirable, because of space requirements, to transfer this flock to the United States Morgan Horse Farm near Middlebury, Vermont. At Middlebury, these animals were also given excellent care. They were fed by themselves during the winter, and received good quality hay, corn silage and grain. In some cases, the Southdowns received second-cutting alfalfa, while other sheep at

[1] Now with the Food and Agriculture Organization of the United Nations, 1201 Connecticut Avenue, N. W., Washington 6, D. C.

the station received first-cutting timothy and clover. From Spring to Fall they were pastured on meadows containing timothy, clover, alfalfa and bluegrass. They seemed to prefer grass to grain while on good pasture but they failed to thrive, as details presented later will show, and were transferred back to Beltsville after about two years. The dates of transfers and of breeding seasons were as follows:

Action	*Date*
Ewes last bred at Beltsville, beginning	—September 24, 1937
Flock transferred to Middlebury	—October 25, 1938
Ewes first bred at Middlebury, beginning	—November 21, 1938
Ewes last bred at Middlebury, beginning	—November 30, 1939
Flock transferred to Beltsville	—September 16, 1940
Ewes first bred at Beltsville, beginning	—September 17, 1940

Details concerning the numbers of animals and fleeces involved in this study are presented in table 1.

TABLE 1. NUMBERS OF ANIMALS FROM WHICH DATA WERE OBTAINED IN THE STUDY OF SOUTHDOWN SHEEP TRANSFERRED FROM BELTSVILLE TO MIDDLEBURY AND BACK TO BELTSVILLE. (1936–1943)

Numbers of animals

Age of ewe	Number of ewes			Number of lambs born			Number of dry ewes		
	Beltsville	Middlebury	Beltsville	Beltsville	Middlebury	Beltsville	Beltsville	Middlebury	Beltsville
1	25	8	11	—	—	—	—	—	—
2	21	9	10	19	9	10	3	0	1
3	21	5	7	23	4	8	1	1	—
4	15	10	5	19	6	8	2	3	—
5	15	8	8	19	6	8	0	2	1
6	6	8	8	7	8	12	1	0	1
7	4	4	6	5	6	6	0	0	1
8	2	2	5	4	3	5	0	0	1

Numbers of animals and fleeces

Age of ewe	Number of lambs weaned			Number of fleece weights			Number of fleece lengths		
	Beltsville	Middlebury	Beltsville	Beltsville	Middlebury	Beltsville	Beltsville	Middlebury	Beltsville
1				25	8	11	25	8	8
2	8	4	5	20	9	10	21	9	10
3	14	4	2	21	5	5	21	5	5
4	12	5	2	14	9	5	15	9	5
5	15	2	6	14	8	8	14	8	8
6	6	7	9	6	8	8	6	8	8
7	3	3	2	4	4	6	4	4	6
8	3	3	4	2	2	5	2	2	5

The responses of the animals, referred to above, to two environments was so strikingly different that earlier records were explored to determine if any supporting or contradictory evidence might be obtained. An earlier transfer of Southdown animals had been made between the two stations. This transfer did not involve the whole flock, but only lambs that were born in 1915 and 1916 at Middlebury, and which were transferred to Beltsville after they were weaned. In order to have lifetime records for comparison, data were assembled on ewes born at Middlebury during 1910 and 1911, and these

TABLE 2. NUMBERS OF ANIMALS FROM WHICH DATA WERE OBTAINED IN THE STUDY OF SOUTHDOWN SHEEP MAINTAINED AT MIDDLEBURY AND BELTSVILLE[1]

Age of ewe	Number of ewes		Number of lambs born		Number of dry ewes		Number of fleece weights		Number of fleece lengths	
	Middlebury	Beltsville	Middlebury	Beltsville	Middlebury	Beltsville	Middlebury	Beltsville	Middlebury	Beltsville
1	34	44	—	—	—	—	34	44	34	44
2	30	36	20	37	14	5	29	33	29	33
3	29	30	35	34	3	5	29	28	29	29
4	27	25	36	28	1	3	27	24	26	24
5	24	23	36	35	1	—	24	23	23	22
6	19	17	29	23	1	1	19	16	19	15
7	14	7	20	6	—	1	13	6	13	6
8	10	4	13	5	1	—	10	4	10	4

[1] Middlebury animals were born at that place in 1910 and 1911, and were maintained there. Beltsville animals were born at Middlebury in 1915 and 1916, and were transferred to Beltsville after weaning.

were compared with the lifetime data on the ewes born in 1915 and 1916 at Middlebury and then transferred to Beltsville. The numbers of animals used in this second phase of the study are shown in table 2.

Details concerning the data obtained in the two phases of the experimental work and explanatory material concerning the data are given in the subsequent section.

Data and Discussion

The average results obtained with the Southdown flock that was shifted from Beltsville to Middlebury and then back to Beltsville are shown in tables 3 and 4. It will be observed from these data that the performance of the animals while at Middlebury was definitely inferior. For example, the ewes of all ages weighed less while at Middlebury than did ewes of similar ages before transfer to that station and after being returned to Beltsville. The percentage lamb crop was also generally higher at Beltsville than at Middlebury, although in two small groups (seven- and eight-year-old ani-

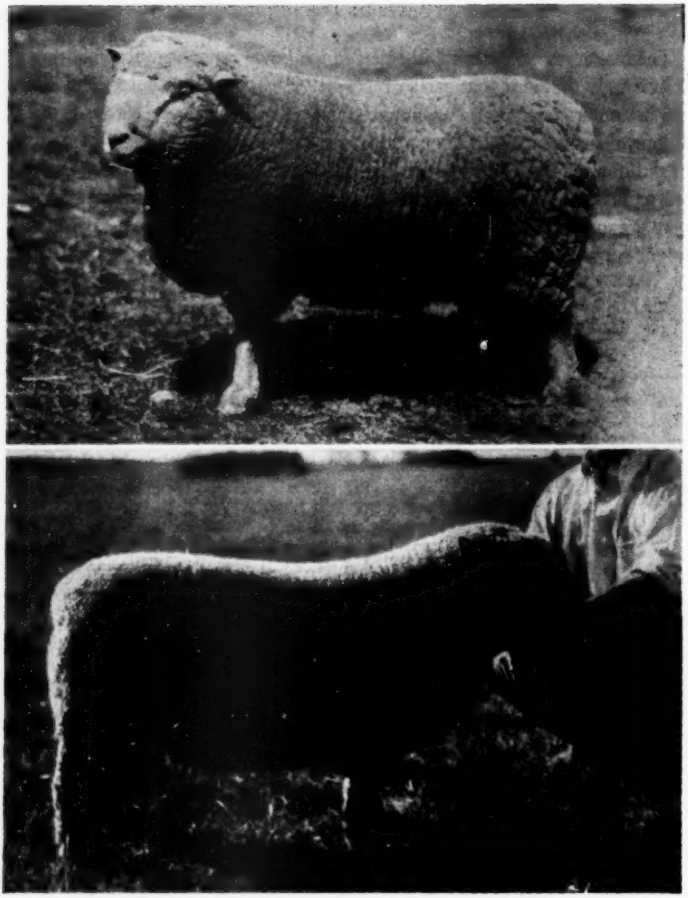

Figure 1. *Top.* Southdown ram, U.S. 31, American Reg. No. 28320. First Southdown ram bred by the Bureau of Animal Industry and used by that Bureau in its Southdown sheep breeding investigations which were conducted at the U.S. Morgan Horse Farm, Middlebury, Vermont. He was born in 1911. He was relatively large and his fleece was relatively heavy but slightly coarser than average for Southdown sheep. (USDA-BAI Negative No. 79597B.) *Bottom.* Southdown ram named Aldenham, 839 of 1932, English Reg. No. 22480, American Reg. No. 84943. This ram was bred by J. Pierpont Morgan, Wall Hall, Walford, Herefordshire, England. He was reserve champion of the English Royal Livestock Show in 1934 when he was acquired by the U. S. Department of Agriculture and brought to the Agricultural Research Center, Beltsville, Maryland, where he was used until he was an old ram. He was also used during the latter part of his life at the U. S. Morgan Horse Farm, Middlebury, Vermont. He presented the very compact, extreme mutton type of Southdown and his offspring were of that same type.

mals), high percentages were recorded at Middlebury. The numbers of animals involved in these cases are too small to attach any importance to the results.

The ewes also appeared to produce less milk while at Middlebury, since the lambs weighed from 10 to 15 lbs. less at weaning time than did lambs from ewes of similar age produced at Beltsville. The effects of the adverse environment may also be seen in the fleece data, since the gross weight and

TABLE 3. DATA ON BODY WEIGHT AND REPRODUCTION OF EWES SUCCESSIVELY AT BELTSVILLE, MIDDLEBURY AND BELTSVILLE DURING THE PERIOD 1936–1943

Age of ewe	Body weight,[1] lbs.			Percentage lamb crop[2]			Percentage dry ewes[3]		
	Beltsville	Middlebury	Beltsville	Beltsville	Middlebury	Beltsville	Beltsville	Middlebury	Beltsville
1	84.7	62.2	82.7	—	—	—	—	—	—
2	89.5	67.4	94.4	105.6	100.0	111.1	14.3	0.0	10.0
3	95.7	73.4	97.0	115.0	100.0	100.0	4.8	20.0	0.0
4	101.2	74.8	111.4	146.2	100.0	180.0	13.3	33.3	0.0
5	106.1	80.7	98.2	126.7	100.0	114.3	0.0	28.6	12.5
6	87.2	86.0	91.1	140.0	100.0	150.0	16.7	0.0	0.0
7	86.0	85.2	96.0	100.0	150.0	120.0	0.0	0.0	16.7
8	95.0	78.0	107.5	200.0	150.0	125.0	0.0	0.0	20.0

[1] All body weights of ewes were taken on October 1 or at the nearest weigh day, with the exception of those for yearling ewes, which were taken on the weighing day nearest one year of age. The weights at Middlebury were taken about one year after arrival and just before transfer back to Beltsville.

[2] Based on number of ewes lambing.

[3] Based on number of ewes in flock at lambing time.

the length of fleece was less in ewes of all ages while at Middlebury than before their transfer to that station or after their return to Beltsville.

The data obtained on Southdown sheep produced in earlier years at Middlebury, some of which were transferred to Beltsville as lambs, are presented in tables 5 and 6. Data obtained in those early years were not as complete as those obtained in the phase of the study already reported. Also, as indicated earlier, the comparisons are not as valid, since the whole flock was not transferred. Therefore, differences in the type of ram used or even differences in the trend of selection within the flock might have had some influence on the results obtained, since five years intervened between the times of breeding of the two groups compared.

It should also be emphasized that the antiquity of these data makes it impossible to get a clear picture of the environmental conditions to which the animals were subjected at the two stations during the years involved. It

seems reasonably certain, however, that the conditions for sheep production during 1915 and subsequent years at Beltsville were not so highly developed as they were during the period 1936–1943. During the intervening period, much attention had been given to the development of temporary pastures and rotation systems for utilizing these pastures, and also to the control of internal parasites. The available data, although inadequate in many respects

TABLE 4. DATA ON PRODUCTION OF EWES AT BELTSVILLE, MIDDLEBURY AND BELTSVILLE DURING THE YEARS 1936–1943

Weights of lambs

Age of ewe	Birth weight of lambs, lbs.			Weaning weight of lambs, lbs.		
	Beltsville	Middlebury	Beltsville	Beltsville	Middlebury	Beltsville
1						
2	5.66	6.12	6.28	47.0	34.2	42.6
3	6.86	6.45	6.42	57.8	32.5	49.0
4	6.72	7.13	5.52	51.3	39.4	44.5
5	7.23	7.35	7.00	54.0	39.5	48.5
6	7.69	7.73	6.14	52.3	42.3	41.3
7	8.60	7.88	8.06	56.0	40.7	47.0
8	6.65	7.73	6.92	44.0	36.3	44.5

Fleece data

Age of ewe	Fleece weight, grease, lbs.[1]			Fleece length, centimetres[1]		
	Beltsville	Middlebury	Beltsville	Beltsville	Middlebury	Beltsville
1	5.93	4.26	5.48	6.73	6.00	6.84
2	5.21	4.17	5.06	5.61	4.59	5.84
3	4.52	3.88	4.98	5.22	4.18	4.83
4	5.04	3.82	5.42	5.31	3.99	5.06
5	4.60	3.78	4.79	4.66	3.88	5.15
6	5.10	3.86	5.11	4.97	4.11	5.50
7	4.00	3.22	4.73	4.32	2.75	5.37
8	4.35	3.20	3.82	4.30	3.05	4.28

[1] The fleece weights and fleece lengths for yearlings were adjusted to 365 days' growth. All others represent one year's growth.

indicate little difference in the performance of the Southdown sheep at the two stations during this phase of the work. The only marked difference is in body weight, and in this case it is in reverse of the other results, the sheep being heavier generally at Middlebury than at Beltsville.

It should also be noted that the animals used in the earlier work (second set of comparisons) were of a larger, more rugged type than those used in

the study conducted later on, and, therefore, may have been better adapted to conditions at Middlebury. Differences in size become apparent if one examines the body weights in tables 3 and 5. If one omits the yearling weights, since none were available from the early data, it is found that averages of groups of animals of various ages in the early work (second set of

TABLE 5. DATA ON BODY WEIGHT AND REPRODUCTION OF EWES BORN AT MIDDLEBURY DURING THE YEARS 1910–1911 AND 1915–1916

Age of ewe	Body weight,[1] lbs.		Percentage lamb crop[2]		Percentage dry ewes[3]	
	Middlebury	Beltsville	Middlebury	Beltsville	Middlebury	Beltsville
1	—	—	—	—	—	—
2	—	125.3	125.0	119.4	46.7	13.9
3	—	122.8	134.6	136.0	10.3	16.7
4	143.4	116.0	138.5	127.3	3.7	12.0
5	151.0	113.2	156.5	152.2	4.2	—
6	146.9	119.2	161.1	143.8	5.3	5.9
7	132.0	102.5	142.9	100.0	—	14.3
8	114.1	101.7	130.0	125.0	10.0	—

[1] All body weights of ewes were taken on October 1, or at the nearest weigh day.
[2] Based on number of ewes lambing.
[3] Based on number of ewes in flock at lambing time.

TABLE 6. DATA ON PRODUCTION OF EWES BORN AT MIDDLEBURY DURING THE YEARS 1910–1911 AND 1915–1916

Age of ewe	Birth weight of lambs, lbs.		Fleece weight, grease, lbs.[1]		Fleece length, centimetres[1]	
	Middlebury	Beltsville	Middlebury	Beltsville	Middlebury	Beltsville
1	—	—	5.38	6.04	6.27	6.36
2	7.79	7.05	7.03	6.29	7.14	5.90
3	7.65	7.45	6.72	6.43	6.18	6.16
4	7.31	7.78	6.65	6.75	5.84	6.62
5	7.60	7.79	6.27	5.35	6.03	5.87
6	8.22	7.51	5.96	4.69	5.75	5.58
7	8.11	9.73	5.80	4.97	5.66	5.39
8	7.98	7.76	5.34	4.12	5.84	4.99

[1] The fleece weights and fleece lengths for yearlings were adjusted to 365 days' growth. All others represent one year's growth.

comparisons) varied from 101.7 to 151.0 pounds, while in the later work the range was from 67.4 to 111.4. The unweighted averages for all age groups, exclusive of yearlings for animals in the early and later work were 124.0 and 90.5 pounds respectively. An importation from England was made in 1934

of 2 rams and 11 ewes, and they were of a relatively small, compact type. These animals and their descendants dominated the breeding of the flock during the period 1936–43

Summary

Two comparisons have been made of the reactions of Southdown sheep to environments at Beltsville, Maryland and Middlebury, Vermont. In one comparison a flock was transferred from Beltsville to Middlebury, and returned to Beltsville after it failed to thrive at Middlebury. In another case, weanling lambs were transferred from Middlebury to Beltsville, and their performance was compared with that of animals born five years earlier and retained at Middlebury.

In the first set of comparisons, (1936–43), ewes of all ages were lighter in body weight at Middlebury than at Beltsville before leaving and after their return. Lambing percentages were also lower at Middlebury in all the age groups having sufficient numbers to give a good indication of average performance. There was no indication of a difference in birth weights at the two locations, but with one minor exception weaning weights were consistently lower at Middlebury, the average difference being about 10 pounds. Fleece lengths and fleece weights were also lower in all age groups at Middlebury.

Weaning weights were not available in the second set of comparisons (1910–24), but there were no consistent indications of differences in performance in animals at Middlebury and Beltsville. However, ewes at Middlebury had heavier body weights in all the five age groups for which data were available.

The reasons for the apparently different reactions in the two comparisons are not entirely clear. Some improvements were made in management and feeding at Beltsville, between the times of the earlier and later comparisons. Five years elapsed between breeding dates of the two groups used in the early experiments so that they may have been less alike genetically than the animals in the flock entering into the later comparisons. Also, the animals used in the early work were of a larger, more rugged type than those used later, and therefore may have been better adapted to the utilization of pasture and hay under conditions at Middlebury.

Even though the reasons for the differences observed in these studies must remain somewhat obscure, the results indicate the importance of variations in adaptability to the environment in livestock production, and point to the need for much greater attention to problems of this type in animal husbandry research.

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SINGLE WEIGHT VERSUS A THREE-DAY AVERAGE WEIGHT FOR SHEEP

H. W. Bean
University of Illinois

MANY research workers follow the practice of taking individual weights of experimental animals on three consecutive days, apparently believing that a single measure does not produce a satisfactory value to represent the weight. In a recent study (Bean, 1946) the author reported no advantage in continuing the practice of obtaining three-day average weights rather than single weights for swine. In a similar test Baker, Phillips, and Black (1947) concluded that there was no advantage in taking the weights of calves on three days when uniform conditions were maintained. Patterson (1947), in a study of steer weights, concluded that "only under exceptional circumstances could it be considered that multiple weighing is an economical method by which to increase the precision of an experiment." In the study here reported, our purpose was to determine whether this same situation held true for sheep.

The weight of an animal is a variable that is influenced by many factors. At any given time it can be measured only approximately, the error depending upon the precision of the scales and the care and accuracy of the observer. Weights of sheep are usually recorded to the nearest pound. A weight recorded as 62 pounds is interpreted to mean that at a particular time the scale reading is closer to 62 than it is to 61 or to 63. The average of three such weights is mathematically accurate only to the nearest pound.

Source of Data

The data used in this study are the actual starting and final weights of lambs from five annual feeding projects conducted at the Illinois Agricultural Experiment Station. Approximately 250 lambs were purchased each year and they were fed in 6 different lots. The 30 lots represented in this study contained a total of 1335 lambs at the beginning of the tests and 1301 at the end. The 34 lambs which were removed from the lots during the course of the experiments apparently represented a random selection from the entire group. There is no evidence to show that their presence in, nor absence from, the data introduces a bias that affects the final conclusion.

Each lamb was weighed individually on three consecutive days at the beginning and end of the test. The averages of each of these three weights were considered the official starting and final weights of the animal. Individual weights were taken at 28-day intervals during the test, but these data were not used in the study.

Results and Discussion

The results of the study show that environment apparently plays an important role in determining the difference between the three-day average and the first-day weights. By environment we mean the weather conditions on the three days on which the weighings are made and also the physical conditions to which the animals are subjected for a period of time previous to weighing.

For the most part the lambs used in this study were weighed a few days after arriving at the station from the western ranges. There were many indications that they were not accustomed to being handled by man. Some outside influence is reflected in the following specific cases.

One lamb weighed 63 pounds on the first day, 55 on the second, and 54 on the third. Its three-day average was 57 pounds, or 6 pounds less than the first-day weight. Another lamb weighed 61 pounds on the first day, 69 on the second, and 74 on the third. Its average was 68 pounds or 7 pounds greater than the first-day weight. These two lambs represent the extreme variations.

In the initial weights the three-day average for 370 animals, or 28 percent of the total, coincided with the first-day weight. For 927, or 69 percent of the total, the deviation was one pound or less. For 1184, or 89 percent, the three-day average was within the range of ± 2 pounds of the first-day weight. The weights of 1300 animals, or 97 percent, were within the range of ± 3 pounds. In 35 the deviation was four pounds or more.

The final weights present a different pattern. During the 90 days the lambs were on test, they apparently became more or less accustomed to their new environment and to handling. They had been weighed at 28-day intervals, and this experience was not new to them. The final three-day averages tended to follow more closely the first-day weights. The two weights coincided in 517 cases, or nearly 40 percent, compared with 28 percent in the initial weights. The range of ± 2 included 99 percent of the final weights compared with 89 percent at the beginning of the experiments.

Table 1 shows the distribution of the deviations of the three-day averages from the first-day weights for both the initial and final weighings.

Apparently the excitement and other factors that affected the weights at the beginning of the experiment were not so influential at the end of the tests. It appears that the three-day average may be biased by outside factors and as a result may not necessarily represent the best measure of weight of the animal at a particular time.

There were 30 lots in this study grouped as the lambs were actually fed. If the animals are on feed and are gaining weight, we should expect an upward trend in the weights on the three consecutive days. However, this trend does not appear to be conclusive in these data.

It should be assumed that the reason for taking three weights is to obtain a more reliable measure to represent the weight. This assumption introduces the hypothesis that a more reliable weight is accompanied by a smaller standard error. In this study the standard error of the mean of the three-day average lot weight was greater than the standard error of the first-day

TABLE 1. DEVIATION OF THE THREE-DAY AVERAGE FROM THE FIRST-DAY WEIGHT, BASED ON 1335 INITIAL AND 1301 FINAL WEIGHTS

Initial weights			Final weights		
Deviation[1] (pounds)	Number of lambs	Percent of total	Deviation[1] (pounds)	Number of lambs	Percent of total
−6	3	.22			
−5	4	.30			
−4	19	1.42			
−3	73	5.47	−3	4	.31
−2	98	7.34	−2	23	1.77
−1	267	20.00	−1	198	15.22
0	370	27.72	0	517	39.74
1	290	21.72	1	456	35.05
2	159	11.91	2	94	7.23
3	43	3.22	3	6	.46
4	4	.30	4	3	.23
5	3	.22			
6	1	.07			
7	1	.07			

[1] The formula for this deviation is $\frac{A+B+C}{3}-A$ when A indicates weight on the first day, B weight on the second day, and C weight on the third day.

weight in 18 lots; the two measures were equal in 10 lots. The three-day average was accompanied by a smaller standard error in 32 lots.

The greatest arithmetic difference in any one lot was between a first-day mean of 66.6 ± 1.2 and its three-day average of 64.7 ± 1.1. The difference between the means was 1.9 pounds, and the difference between the standard errors was .1 pound. The standard error of the difference between these two measures did not exceed 1.4 pounds in any lot. This difference can be expected in chance variation at least once in ten trials and is not significant.

The total variation which occurred in all weights can be separated into parts some of which are designated as the variation between days, years, lots within years, and animals within lots. The variation between daily

weights constituted but a very small portion of the total variation. A few lots selected by chance tended to show that less than one percent of the total variation could be attributed to the difference between daily weights. The range of the calculated percentages was from 0.11 to 1.24. When all initial weights were considered, there was no difference between the means of the daily weights. The average of all lambs was 67.2 pounds on each of the three days. Since there was no variation between daily weights all of the variation is within these particular groups.

Table 2 shows the variation between animals within lots calculated on the

TABLE 2. VARIATION BETWEEN ANIMALS WITHIN LOTS

	D.F.	Mean square
Initial Weights		
First-day weight	1301	49.52
Three-day average	1301	47.46
Final Weights		
First-day weight	1267	94.65
Three-day average	1267	96.61

basis of first-day weights and also on the three-day average. These data show that in the initial weights the mean square for the three-day average is 4.2 percent less than the mean square for the first-day weight. In the final weights the opposite relation exists with the mean square being increased by 2.1 percent when the three-day average is taken.

This study indicates that a single weight is as reliable as the average of three consecutive daily weights.

Summary

Environment seems to play an important role in determining the three-day average weight of sheep.

In these data there is no significant difference between the lot weights obtained on the first day and those obtained from the three-day averages.

The standard error of the mean is not invariably reduced by taking the mean of three daily weights. The greatest reduction for these data was .1 pound.

In this test the extra work involved in weighing on three consecutive days did not result in increased accuracy and therefore did not produce the results for which it was intended.

There seems to be no justification for continuing the practice of weighing an experimental animal on three consecutive days. One weighing, in which

the scales are accurately read, usually will more nearly represent the actual weight of an animal than will the average of three weights taken at twenty four-hour intervals.

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LINEARITY OF REGRESSION OF MILK ENERGY ON FAT PERCENTAGE

O. R. Overman and W. L. Gaines
Illinois Agricultural Experiment Station[1]

Introduction

As early as 1920 Stocking and Brew (1920) reported milk energy per pound of milk as a linear function of fat percentage. They expressed solids-not-fat percentage as a linear function of fat percentage and computed energy value of the milk as 4220 kcal./lb. fat plus 1860 kcal./lb. solids-not-fat. The figures in the first three lines of the following tabulation are copied from their article:

Fat, % (*f*)	3.0	4.0	5.0	6.0
Solids-not-fat, %	8.3	8.7	9.1	9.5
Kcal./lb. milk	280.98	330.62	380.26	429.90
Relative energy	.85	1.00	1.15	1.30

From the last line Gaines and Davidson (1923) derived the formula, $FCM = M\ (.4 + .15\ f)$ or $FCM = .4\ M + 15\ F$, in which *FCM* is milk energy in terms of pounds of natural whole cows' milk of 4 percent fat content, M is milk in pounds and F is milk fat in pounds.

Recently, Bonnier, Hansson and Jarl (1946) report that the regression of milk energy per unit milk on fat percentage is not linear and present a table for computing milk energy in terms of 4 percent milk, based on a graphically-smoothed regression line obtained from chemical analyses of 2152 milk samples. The samples came from the identical twins, and other cows, at the Institute of Breeding, Wiad, Sweden, and represent short periods at various stages of lactation. Their smoothed curve showing the regression of milk energy on fat percentage is concave upward. Range of fat percentage was from 2.11 to 7.28.

The $.4\ M + 15$ F formula for estimating milk energy is now in wide use and it seems desirable, therefore, to consider carefully the curvilinear modification advocated by Bonnier. The present paper considers three sets of observations from the linearity angle:

Set 1. These are data of Overman and Sanmann (1927) and consist of 212 3-day samples from cows of several breeds at the Illinois Station, at various stages of lactation. Fat percentage was determined by chemical analysis. Milk energy was determined by direct calorimetry. Range of fat percentage was from 2.68 to 7.59.

[1] Department of Dairy Husbandry, University of Illinois, Urbana, Illinois.

Set 2. These are data of Forbes (1935) and consist of 138 28-day samples from 14 Holstein cows at the Pennsylvania Institute of Animal Nutrition, at various stages of lactation. Fat percentage was determined by chemical analysis. Milk energy was determined by direct calorimetry. Range of fat percentage was from 2.55 to 6.23.

Set 3. These are data of Gaines and Overman (1938) and consist of 305-day samples of 130 purebred and crossbred cows at the Illinois Station. The samples were built up from 1519 3-day samples at intervals of four or five weeks, to represent the 305-day partial lactation. In 32 cases the samples represent the average of two or three 305-day partial lactations of the given cow. Fat percentage was determined by chemical analysis. Milk energy was computed from chemical analysis for various milk components. Range in fat percentage for the 130 samples was from 2.92 to 6.00.

Statistical Procedure and Results

Each set of observations is fitted, by least squares, with the linear equation, $Y = \text{kcal./kg. milk} = a + bf$ and also with curvilinear equation, $Y = a + bf + cf^2$. The standard error if c is also derived. Comparison of c with its standard error affords one test of linearity, assuming the term in f^2 is adequate to describe any departure from linearity. If c is not significant the regression may be considered linear. Following are the fitted equations, numbered to correspond with the sets of observations:

(1a) $Y = 286.9 + 115.7\,f$

(1b) $Y = 208.7 + 152.2\,f - (4.07 \pm 1.14)\,f^2$

(2a) $Y = 267.2 + 121.0\,f$

(2b) $Y = 158.8 + 178.8\,f - (7.49 \pm 2.54)\,f^2$

(3a) $Y = 304.9 + 114.1\,f$

(3b) $Y = 308.6 + 112.3\,f + (.20 \pm 2.14)\,f^2$

Equation (3b) agrees with Bonnier's result in that the regression line is concave upward but the departure from linearity is not significant since c is even smaller than its standard error.

In equations (1b) and (2b) c is significant but in each the regression line is concave downward, just the opposite of Bonnier's result. The observations represented by equation (1b) should be comparable with those of Bonnier. His observations are more extensive in number, 2152 vs. 212, but the 212 observations have the advantage of direct calorimetric determination of kcal/kg. milk (Y). Here we have two independent sets of observations which agree in indicating that the regression of Y on f is significantly not linear, in a probability sense. But one regression line is concave upward while the other is concave downward. Is it safe or desirable to generalize from either

one to the extent of formulating a curvilinear plan of estimating Y from f? Is it not safer to assume that in general the regression of Y on f is linear? The linear assumption is decidedly more simple in practical use.

The meticulous observations of Forbes, set 2, are also significantly (in a probability sense) curvilinear[2] in the regression of Y on f, with the regression line concave downward. The Forbes data, therefore, further question the advisability of adopting the concave-upward, graphically-fitted regression line of Bonnier, for general use.

In some respects the observations of set 3 seem entitled to considerable weight, because they represent 305-day partial lactation periods of individual cows. For this set of observations there is no question about linearity of regression of Y on f. Equation (3a) yields the formula, $FCM = .4005\ M + 14.99\ F$, which is practically the same as the general $.4\ M + 15$ F formula.[3] The observations of set 3 seem most appropriate from the standpoint of estimating milk-energy yield of individual cows, where milk yield and milk-fat yield are known, and more detailed data are lacking. If greater refinement in energy determination is required, direct calorimetric determinations should be carried out.

Perhaps the differences between the observations of set 1 and set 3 are associated with stage of lactation. It would be of interest to carry through the analysis, within stage of lactation (and also within cow, that is between stages, within cow). A practical application of such an analysis would be in connection with feeding standards, which have to fit the lactation needs of the cow at various stages of lactation.

Table 1 affords another test of linearity of the regression of Y on f with an outcome essentially similar to that of the foregoing equations. In set 1 and set 2 the variance traceable to curvilinearity is significant at above the 1 percent level; in set 3 the variance traceable to curvilinearity is almost nil and well below the 5 percent level of significance. The observations of set 1 and of set 2 in table 1 support Bonnier's contention that the regression of Y on f is significantly not linear. Table 1 does not reveal that the regression line is concave downward, the opposite of Bonnier's regression line. This difference seems to be of prime importance in deriving a regression equation for general application.

[2] It has been found (Gaines, 1943, footnote 9) from the Forbes data that the correlation between the directly determined kcal. yield by 28-day periods and FCM yield ($.4\ M + 15\ F$) for the same periods is .997. Clearly the linear estimate of milk energy by the $.4\ M + 15\ F$ formula has a good deal of interest and practical utility in spite of the significant curvilinearity of the regression of Y on f. Significance in a probability sense is one thing; significance in practical application may be a somewhat different thing. The finding of Bonnier that the regression of Y on f is significantly (in a probability sense) not linear, like the present equations (1b) and (2b), does not mean that we must abandon the linear, $.4\ M + 15\ F$ formula.

[3] Equation (1a) yields the formula, $FCM = .3828\ M + 15.43\ F$; equation (2a), $FCM = .3557\ M + 16.11\ F$; and Bonnier reports for his data on a linear basis, $FCM = .4020\ M + 14.95\ F$.

TABLE 1. LINEARITY OF REGRESSION OF kcal./kg. MILK ON FAT PERCENTAGE

Observations	Source of variation	Degrees of freedom	Mean square	F
Set 1	Deviation from linear	210	325.8	
	Deviation from curvilinear	209	308.4	
	Curvilinearity of regression	1	3952.3	12.83**
Set 2	Deviation from linear	136	308.6	
	Deviation from curvilinear	135	292.0	
	Curvilinearity of regression	1	2544.9	8.72**
Set 3	Deviation from linear	128	168.6	
	Deviation from curvilinear	127	169.9	
	Curvilinearity of regression	1	1.5	113.29

** Significant at the 1% level, from table 10.7 of Snedecor (1946).

Summary and Conclusions

This article considers the contention of Bonnier, Hansson and Jarl (1946) that the regression of kcal/kg. milk (Y) on fat percentage (f) is significantly not linear, and that the estimation of milk energy in terms of 4 percent milk should be made on the basis of their graphically-smoothed regression line, which is concave upward. Three sets of observations on Y and f are examined in the present article, from the linearity angle.

Two sets agree with their results in being significantly not linear, but in each set the fitted regression line is concave downward, the opposite of their results. It seems unsafe and unwise to generalize the estimate of milk energy on the basis of either a concave-upward or a concave-downward regression line. A compromise between the two seems to offer a safer genralization, namely, a fitted linear regression. The quantitative difference between the linear and curvilinear regression lines is very small.

The third set of observations on Y and f is strictly linear, by statistical test, and yields the formula $FCM = .4005\ M + 14.99\ F$.

It is concluded that the evidence at present available indicates no need to modify the estimation of milk energy in terms of 4 percent milk by the $.4\ M + 15\ F$ formula, as a generalization.

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EFFECTIVENESS OF CAROTENE AND FAILURE OF ASCORBIC ACID TO INCREASE SEXUAL ACTIVITY AND SEMEN QUALITY OF VITAMIN A DEFICIENT BEEF BULLS

LOUIS L. MADSEN,[1] O. N. EATON, LOUIS HEEMSTRA, RUSSELL E. DAVIS, CHARLES A. CABELL, AND BRADFORD KNAPP, JR.

United States Department of Agriculture

IT IS generally accepted that the amount of vitamin A or carotene needed for normal reproduction in cows is greater than the amount needed for protection against a well known symptom of vitamin A deficiency, night-blindness. Less is known concerning the minimum amount of this factor needed by bulls for optimum breeding performance. The work of Sutton, Kraus and Hansard (1940), Thorp *et al.* (1942), and Erb *et al.* (1944) shows that severe vitamin A deficiency results in structural injury to the germinal epithelium of the testes and inhibition of normal spermatogenesis. Observations on dairy bulls reported by Reed (1942, 1943), however, indicate that vitamin A deficiency may result in blindness in young bulls and weakness and other indications of prolonged vitamin A deficiency in older animals before there is marked impairment of semen quality or reproductive ability. In these studies it was found that semen samples from vitamin A deficient dairy bulls were fertile on artificial insemination in several instances. The purpose of this paper is to report certain observations and results of chemical determinations on the semen and blood plasma of young beef bulls maintained on apparently adequate levels of carotene and to note changes in semen quality and other factors during a period of vitamin A depletion followed by treatment with ascorbic acid and carotene.

Materials and Methods

Six young crossbred (Hereford × Shorthorn) bulls were used in this study. They were offspring from cows that had been partially depleted of vitamin A as heifers (Davis and Madsen, 1941), and then fed controlled levels of carotene from alfalfa meal. The animals were designated A, B, C, D, E, and F. The first five were fed the same levels of crude carotene furnished by alfalfa meal that their dams received, which were, respectively, 45, 50, 60, 60, and 90 micrograms of carotene per kilogram of body weight daily. The carotene intake of bull F varied from 140 to about 40 micrograms since this animal was fed 2 kilograms of U. S. No. 1 alfalfa hay daily and the carotene intake was determined by the carotene content of the hay which became progressively less as the hay was held in storage. The carotene intake

[1] Now head, Department of Animal Husbandry, Utah State Agricultural College, Logan, Utah.

of the other calves was adjusted weekly according to body weight. All of the bull calves except C were weaned at 10 months of age. Bull C was hand fed whole milk until 8 months of age. All six calves were fed the same carotene deficient basal grain mixture with oat straw as roughage (Davis and Madsen 1941). Grain and alfalfa meal feeding started when the calves were 30 days old.

The carotene content of the alfalfa used was determined by a modification of the Willstätter and Stoll procedure essentially as outlined by Wiseman *et al.* (1938). The carotene content of the resulting extract was estimated by means of a spectrograph with a photometer attachment. Plasma carotene and vitamin A were estimated by methods previously described by Madsen and Davis (1938), and Davis and Madsen (1941). Plasma and semen vitamin C was determined by an adaptation of the Mindlin and Butler (1938) method.

Semen samples were obtained by the use of artificial vaginas, and observations on motility, volume, number of spermatozoa and proportion and types of abnormal sperm were determined essentially as outlined by Phillips *et al.* (1943). Collection of semen samples was started on July 17, 1942 and continued at weekly or biweekly intervals for a period of approximately 25 months. At the time semen collections were started, bulls A, B, C, D, E, and F were approximately 15, 14, 18½, 14, 15 and 26½ months of age respectively.

Results and Discussions

During a preliminary observation period from July 17 to September 25, 1942, satisfactory semen collections were made weekly from all animals except bull A. This bull, on the 45 microgram level of carotene, had shown various symptoms of vitamin A deficiency as a calf, but deficiency symptoms largely disappeared as the animal grew older. The animal never demonstrated copulatory ability, yet when slaughtered at two years of age, histological examination of the testes showed active spermatogenesis and spermatozoa were present in the epididymal tubules. Average values for observations on motility score, volume of ejaculate, concentration of spermatozoa and percentage of abnormal spermatozoa on weekly collections of semen from the individual experimental bulls during the preliminary period compared favorably with similar observations reported by Phillips, *et al.* (1943), from apparently normal Shorthorn bulls maintained at the Beltsville Research Center. No differences in semen characteristics were evident that could be ascribed to the level of carotene intake at this time.

At the end of the preliminary period, bulls C and F were selected for vitamin A depletion. This was accomplished by withdrawing alfalfa from their ration, beginning on October 7. Bulls B, D, and E were continued on

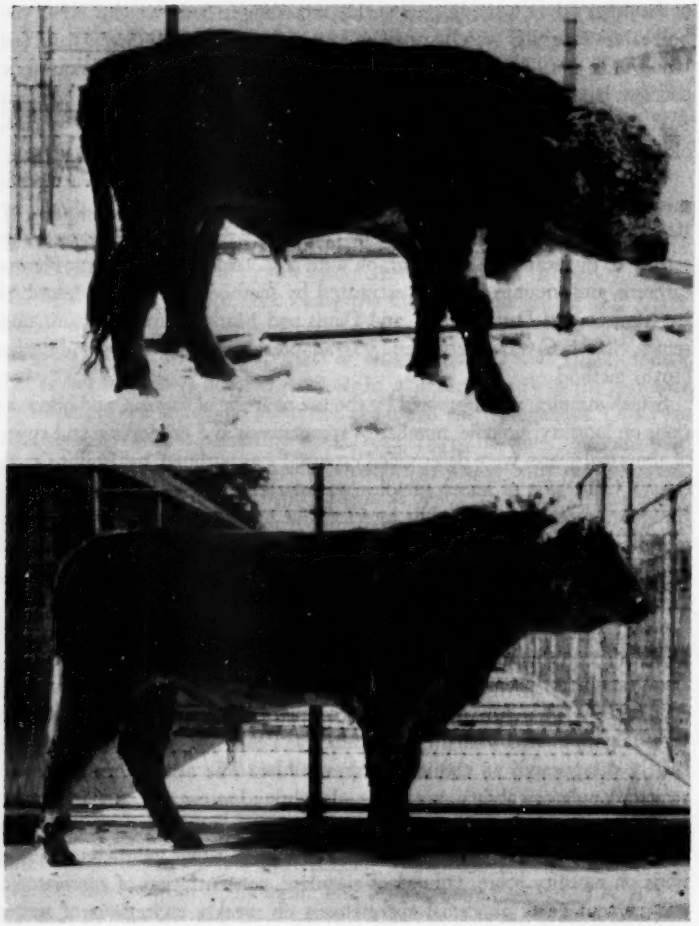

Figure 1. Top. Shows bull F in an advanced stage of vitamin A deficiency. Note rough haircoat and dejected appearance. Bottom. Carotene feeding was followed by a rapid disappearance of the symptoms of vitamin A deficiency and a marked improvement in general appearance and male characteristics.

their respective levels of carotene intake to serve as controls. Symptoms of vitamin A deficiency appeared somewhat earlier in bull F than in bull C. Incoordination on mounting, however, was evident by November 9 (34

days), and by December 9 (64 days) noticeable impairment of day vision had developed in both bulls. By January 15, 1943 (101 days) occasional convulsions and swelling of the hind legs or anasarca (Creech and Madsen, 1942; Madsen, 1942) had developed.

Sexual desire and ability decreased rapidly with the onset of vitamin A deficiency symptoms. Incoordination and lack of vigor on mounting were noted first. Libido continued to decline until little or no sexual interest could be aroused after the bulls had been on the carotene deficient rations for about 3 months. At this time the scrotum of both bulls was markedly retracted as compared with its former appearance or as contrasted to the condition in the control bulls at the same time. The hair coat of the deficient bulls became dry and harsh, and had a "dusty" unkempt appearance.

Ascorbic acid therapy[2] was started on bull F on January 6, 1943, and on February 3 on bull C, after they had been on the carotene deficient diet for 92 and 120 days, respectively. Bull F was still continuing to give service at this time, but he was very slow and had very poor ability. Sexual desire and ability of bull F continued to decrease during 3 weeks of treatment with ascorbic acid. During this time convulsions, swelling of the legs, decline in appetite, and weakness reached a critical stage (see figure 1—Top). Vitamin C injections were therefore discontinued and carotene feeding[3] started on January 27 after 113 days of carotene depletion. Following this change, there was a marked improvement in appetite within 2 days and moderate sexual desire returned within 7 days. Successful service was obtained 14 days after carotene feeding and quite regularly thereafter. The response following carotene therapy was considered remarkable (see figure 1—Bottom).

Bull C went totally blind approximately at the same time that ascorbic acid therapy was started. Despite this handicap, his appetite remained good and the other symptoms of vitamin A deficiency did not progress so quickly as in the case of F. Ascorbic acid therapy was continued regularly until April 7, or a total of 63 days, and no sexual interest was evident during numerous trials in this period. After this time, ascorbic acid injections were discontinued until June 2, at which time injections of ascorbic acid were resumed again every other day instead of twice weekly as before. During this treatment, the animal became weaker, convulsions increased, and incoordination became severe, presumably due to advanced vitamin A deficiency. Ascorbic acid was discontinued and carotene feeding started on June 19 after 256 days of carotene depletion. This change was followed by a progressive

[2] Ascorbic acid was dissolved in sterile phosphate buffer at pH 6.8 and injected subcutaneously at the rate of 5 milligrams per kilogram of body weight twice weekly.

[3] Five grams of a commercial carotene concentrate were fed in oil solution three times weekly. This dosage provided approximately 34 milligrams of carotene per day.

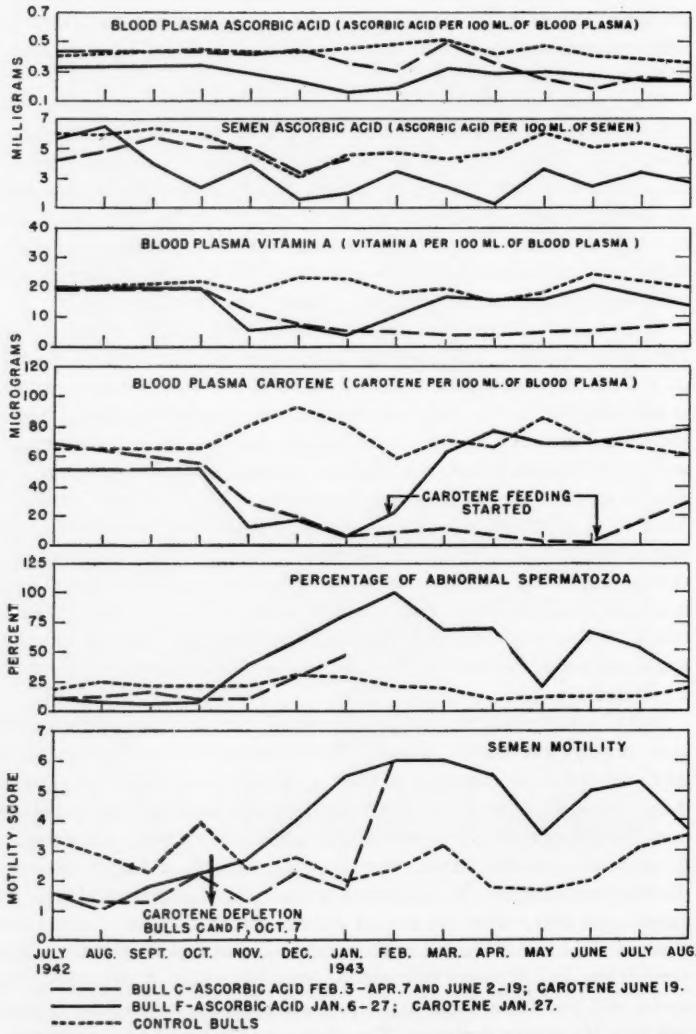
BLOOD PLASMA ASCORBIC ACID (ASCORBIC ACID PER 100 ML. OF BLOOD PLASMA)
MILLIGRAMS
SEMEN ASCORBIC ACID (ASCORBIC ACID PER 100 ML. OF SEMEN)
BLOOD PLASMA VITAMIN A (VITAMIN A PER 100 ML. OF BLOOD PLASMA)
MICROGRAMS
BLOOD PLASMA CAROTENE (CAROTENE PER 100 ML. OF BLOOD PLASMA)
CAROTENE FEEDING STARTED
PERCENTAGE OF ABNORMAL SPERMATOZOA
PERCENT
SEMEN MOTILITY
MOTILITY SCORE
CAROTENE DEPLETION BULLS C AND F, OCT. 7
JULY 1942 AUG. SEPT. OCT. NOV. DEC. JAN. 1943 FEB. MAR. APR. MAY JUNE JULY AUG.
BULL C - ASCORBIC ACID FEB. 3 - APR. 7 AND JUNE 2-19; CAROTENE JUNE 19.
BULL F - ASCORBIC ACID JAN. 6-27; CAROTENE JAN. 27.
CONTROL BULLS

Figure 2. Changes in semen motility and percentage of abnormal spermatozoa associated with carotene, vitamin A, and ascorbic acid in blood plasma and semen.

disappearance of all symptoms of vitamin A deficiency except blindness which remained permanent. A noticeable return of sexual desire was evident 18 days later. The first successful semen collection was made in August but collections continued somewhat irregularly until the following November after which regular service was obtained.

The performance of the three control bulls was relatively consistent so in order to simplify presentation of data, their values were averaged together for comparison with records of the bulls subjected to Vitmain A deficiency and therapy. Average data on semen motility,[4] percentage of abnormal spermatozoa, and the chemical determination of carotene, vitamin A and ascorbic acid in the blood plasma and semen are given in figure 2 by monthly periods from July 1942 to and including August 1943. Data on the average volume of semen and total spermatozoa produced to and including August, 1944 are given in table 1.

The graphs in figure 2 indicate a rather close relationship between semen motility, percentage of abnormal spermatozoa and blood plasma carotene and vitamin A. This is particularly true with respect to the bulls subjected to vitamin A deficiency. Bull F appeared to deplete somewhat faster than bull C as previously noted, and this was reflected by a more rapid decline in blood plasma, carotene and vitmain A. This was also associated with an earlier and greater increase in percentage of abnormal spermatozoa followed by a progressive decrease in semen motility and number of spermatozoa produced (table 1). The last semen sample collected during the period of carotene deficiency from bull C (February 10, 1943) showed no motility, the amount ejaculated was unusually small, and contained only 48 million spermatozoa (table 1). No differential count was made on this particular sample, but samples collected during the previous two months showed an increase in percentage of abnormal spermatozoa. Semen and blood plasma ascorbic acid also decreased during the period of vitamin A deficiency.

Bull F responded to carotene therapy with prompt increases in plasma carotene and vitamin A. After some delay, the percentage of abnormal spermatozoa decreased gradually and the motility and number of spermatozoa increased. In May 1943, the average percentage of abnormal spermatozoa was unusually low and the samples showed improved motility; however, a secondary increase in abnormal spermatozoa with a corresponding decrease in motility score characterized the two following months. The semen continued to improve and become essentially normal during the following year.

The response of bull C to carotene after ascorbic acid therapy had failed was just as definite as in the case of bull F. The first semen sample obtained

[4] Score for motility: 1, Most active, progressive action. 2. Less active, but progressive. 3, Quiet progressive motion. 4, Weak progressive motion. 5, Motile but not progressive. 6, Nonmotile.

TABLE 1. AVERAGE VOLUME OF SEMEN AND TOTAL SPERMATOZOA PRODUCED BY BULLS DURING MONTHLY PERIODS

Year	Month	Semen volume			Total spermatozoa		
		Controls	Bull C	Bull F	Controls	Bull C	Bull F
		ml.	*ml.*	*ml.*	*millions*	*millions*	*millions*
1942	July	3.52	2.25	5.25	1778	1528	3795
	Aug.	2.68	3.22	3.97	1469	1403	2982
	Sept.	3.38	2.75	3.30	1792	1669	3082
	Oct.	4.96	5.17[1]	4.27[1]	3203	3407	2734
	Nov.	5.19	4.57	4.67	4167	3955	3978
	Dec.	4.59	5.97	4.60	3409	9374	2695
1943	Jan.	3.92	4.33	5.17[2]	2861	5975	1604
	Feb.	3.84	.80[3]	7.00	2825	48	700
	Mar.	3.58	N.S.[4]	4.66	3058	N.S.	621
	April	3.58	N.S.	3.72	2828	N.S.	772
	May	4.63	N.S.	4.00	3626	N.S.	1904
	June	3.61	N.S.[5]	3.50	3545	N.S.	1429
	July	3.49	N.S.	3.75	3198	N.S.	1948
	Aug.	3.24	5.50	2.65	3523	1320	1850
	Sept.–Nov.	4.17	5.80	3.91	3479	7482	1056
	Dec.–Feb.	[6]	4.96	3.28	[6]	4796	1105
1944	Mar.–May		5.51	4.10		4128	2032
	June–Aug.		3.40	5.21		1700	2581

[1] Carotene depletion started October 7 on bulls C and F.

[2] Bull F: Ascorbic acid injections given January 6 to 27; carotene feeding started January 27.

[3] Bull C: Ascorbic acid injections given twice weekly from February 3 to April 7.

[4] N.S. indicates that no sample could be obtained.

[5] Bull C: Ascorbic acid injections resumed June 2 and given on alternate days until June 19; carotene feeding started June 19.

[6] Controls discontinued.

in August following carotene feeding showed only slight motility and a high proportion of abnormal spermatozoa, but the number of spermatozoa produced compared favorably with the number during this preliminary period for this bull (table 1). No samples could be obtained from this bull during September and October. Samples appeared essentially normal in November and December and remained so thereafter.

The percentage distribution of the various types of abnormalities found in the spermatozoa from the control bulls and the bulls subjected to vitamin A deficiency is given in table 2. The semen from the control bulls had the lowest percentage of abnormal spermatozoa during March to July inclusive. Maximum numbers of abnormal spermatozoa appeared in December and January.

Prior to the period of vitamin A depletion, the semen of bulls C and F averaged lower in abnormal spermatozoa than the controls. In November

TABLE 2. AVERAGE PERCENTAGE OF VARIOUS TYPES OF ABNORMAL SPERMATOZOA PRODUCED DURING MONTHLY PERIODS

Year	Month	Percentage of abnormalities in indicated parts of spermatozoa									Total percentage of abnormal spermatozoa		
		Head			Middle piece			Tail					
		Controls	Bull C	Bull F	Controls	Bull C	Bull F	Controls	Bull C	Bull F	Controls	Bull C	Bull F
1942	July	5.3	3.0	3.5	4.6	3.2	2.2	8.4	4.6	5.3	18.3	10.8	11.0
	Aug.	10.2	2.0	3.9	2.5	3.2	1.7	12.0	7.7	2.2	24.7	12.9	7.8
	Sept.	10.0	6.7	2.5	3.1	6.1	2.3	9.2	3.5	2.1	22.3	16.3	6.9
	Oct.	10.4	4.6[1]	2.8[1]	2.6	2.3	1.5	8.4	4.4	3.8	21.4	11.3	8.1
	Nov.	12.2	6.7	26.5	4.4	2.8	6.2	5.4	2.1	4.1	22.0	11.6	36.8
	Dec.	17.6	18.1	43.2	5.8	5.8	8.3	7.5	3.9	7.6	30.9	27.8	59.1
1943	Jan.	16.5	38.2	63.8[2]	6.2	7.1	10.3	6.1	2.6	8.0	28.8	47.9	82.1
	Feb.	13.3	N.D.[3]	98.8	4.5	N.D.	0.8	4.2	N.D.	0.2	22.0	N.D.	99.8
	Mar.	9.2	N.S.[4]	58.9	2.9	N.S.	6.8	6.4	N.S.	2.8	18.5	N.S.	68.5
	Apr.	6.0	N.S.	36.9	1.3	N.S.	4.0	3.0	N.S.	8.6	10.3	N.S.	69.5
	May	8.9	N.S.	12.5	2.2	N.S.	1.3	2.5	N.S.	6.7	13.6	N.S.	20.5
	June	8.9	N.S.[5]	60.7	1.3	N.S.	2.2	3.1	N.S.	4.5	13.3	N.S.	67.4
	July	9.8	N.S.	46.9	0.5	N.S.	2.3	2.3	N.S.	5.5	12.6	N.S.	54.7
	Aug.	12.4	49.8	18.5	1.6	2.4	2.2	5.6	1.4	6.8	19.6	53.6	27.5
	Sept.–Nov.	12.0	2.1	49.7	1.2	1.2	6.2	6.2	1.4	4.9	19.4	4.7	60.8
	Dec.–												
1944	Feb.	[6]	3.4	14.9	[6]	0.5	2.9	[6]	1.4	21.6	[6]	5.3	39.4
	Mar.–May		2.1	8.6		0.3	0.9		3.8	6.9		6.2	16.4
	June–Aug.		4.2	8.3		1.6	1.5		0.4	6.0		6.2	15.8

For footnotes 1, 2, 4, 5 and 6 see table 1.
[3] N.D. indicates no differential count made.

1942, the month after the carotene-deficient ration was started, bull F showed a marked increase in spermatozoa with small and abnormally shaped heads, broken necks, and misplaced and bent or broken middle pieces. The percentage of abnormal forms increased further in January during ascorbic acid therapy and reached a maximum (99.8 percent) in February, following carotene therapy. In March, the number of spermatozoa with broken necks (tailless heads) decreased markedly, but there was an increase in forms with small heads (microspermia). The number of abnormal spermatozoa continued high but variable during the folllowing year, but thereafter became essentially normal in this respect.

Abnormal spermatozoa appeared in larger numbers during December, or in the second month on the carotene deficient ration, in bull C. Abnormally shaped heads and broken necks were the most prominent forms. Samples in January showed a further increase in abnormal forms. When service was resumed in August 1943, after carotene therapy, the semen of this bull contained a large number of spermatozoa with small heads and other abnormal forms. Samples collected in November and thereafter were apparently normal.

During the period of severe carotene deficiency semen smears from bulls C and F usually showed large quantities of cellular debris among which were round nucleated cells, squamous epithelial cells, sheets of desquamated epithelium and other unidentified material. This material disappeared as the bulls recovered from vitamin A deficiency.

Bulls C and F sired normal calves following recovery due to carotene feeding. The bulls were slaughtered on October 10, 1944. A large cystic pituitary gland similar to those previously reported by Madsen *et al.* (1942), was found in each. Their testicles appeared essentially normal, but on histological examination evidence of previous damage presumably due to vitamin A deficiency was found. This consisted of tubules with no germinal epithelium, and other tubules where the epithelium was very loose in structure and unusually thin, sometimes being only one or two cells deep. Some areas were apparently normal. Mitosis and spermatogenesis appeared active.

These findings on a small group of bulls indicate that severe carotene or vitamin A deficiency readily affects sexual interest and quality of semen produced. Facilities were not available to test the fertility of the semen samples containing a high percentage of abnormal spermatozoa. Bull F, however, sired a calf during his recovery period when he still had about 69 percent of abnormal spermatozoa. In view of the evidence of previous injury to the germinal epithelium of the testes found on histological examination after approximately 20 months of carotene feeding in the case of bull F and about 16 months in the case of bull C, one may assume that their reproductive capacity might have been correspondingly reduced, if subjected to frequent service.

In this study on beef bulls the effects of vitamin A deficiency on sexual activity and semen quality appeared to parallel the appearance of other symptoms of vitamin A deficiency and in this respect seem to differ from the results cited by Reed (1942, 1943), with dairy bulls. Exact comparisons cannot be drawn, however, since several factors such as age of animal, vitamin A storage of the animals at the beginning of the depletion period, and possibly other factors which may have an influence on the results obtained were not comparable.

Summary and Conclusions

Observations are recorded on the reproductive performance of six beef bulls reared on a carotene deficient basal diet supplemented with restricted levels of alfalfa, which furnished 45 to 140 micrograms of crude carotene per kilogram of body weight daily. One bull on the 45 microgram level showed symptoms of vitamin A deficiency as a calf and later failed to demonstrate copulatory ability. Successful semen collections and fertility were established

in the other five bulls, all of which received 50 micrograms or more of crude carotene per kilogram of live weight. At the end of a preliminary semen collection period, two of the bulls were subjected to a period of vitamin A depletion, and the other three continued on their respective levels of carotene intake for control observations. The progress of the degree of vitamin A deficiency was followed by chemical determinations of carotene and vitamin A in the blood plasma and ascorbic acid in the blood plasma and semen. Sexual activity and ability decreased rapidly with the development of symptoms of vitamin A deficiency. Semen samples collected as the depletion progressed showed marked increases in percentage of abnormal spermatozoa and cellular debris with progressive decline in motility.

Injections of ascorbic acid failed to stimulate sexual activity or modify the quality of the semen produced by the carotene deficient bulls. Carotene feeding, on the other hand, restored the bulls to apparently normal activity and semen production. Histological evidence of previous testicular injury due presumably to vitamin A deficiency was evident after as long as 20 months of carotene feeding.

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RELATION OF TYPICAL POSTNATAL CHANGES IN THE DIET OF THE DAIRY CALF TO THE CONCENTRATION OF CAROTENOIDS AND VITAMIN A IN THE BLOOD SERUM[1]

G. H. Wise,[2] M. J. Caldwell,[3] D. B. Parrish,
F. W. Atkeson and J. S. Hughes
Kansas Agricultural Experiment Station

THE high incidence of morbidity and mortality among dairy calves subjected to modern feeding and managerial practices continues to be one of the major obstacles to herd improvement and expansion. Consideration of the problem from a nutritional standpoint has focused attention on the vitamin needs of the calf. The essential role of vitamin A in maintaining the normal physiological processes in animals and the wide variability of vitamin A activity in dairy feeds have introduced the question of the adequacy of this nutriment in commonly recommended and widely used calf diets.

A practical approach to the problem has been made by observing the effects of vitamin A supplementation on the health and the growth of calves. The results, reviewed by Gullickson and Fitch (1944), ranged from no discernible advantage to marked benefits. The responses apparently varied with the quality of the control diets.

Though chemical assays of the blood have been used as a criterion of the vitamin A nutrition of calves, this index has not been applied extensively in determining the degree to which common calf rations, fed according to accepted systems, meet the vitamin A needs of the young calf (Lundquist and Phillips, 1943; Moore and Berry, 1944 and 1945; Nelson *et al.*, 1944; Phillips *et al.*, 1941). Hence, the investigation reported herein was directed toward further exploration of the relation of typical dietary changes to the trends and variations in the carotenoid and vitamin A content of the blood serum of calves during the critical transitional stages of early postnatal development.

Methods

During the summer months of 1946, measurements of the concentrations of carotenoids and of vitamin A were made on serum from individual samples of venous blood collected periodically from 11 normal dairy calves. The experimental period, from birth to 10 weeks of age, included the primary dietary transitions from colostrum to roughage.

[1] Contribution No. 167, Department of Dairy Husbandry, and No. 331, Department of Chemistry, Kansas Agricultural Experiment Station, Manhattan, Kansas.

[2] Present Address, Department of Animal Husbandry, Iowa State College, Ames, Iowa.

[3] Now with Moorman Mfg. Co., Quincy, Ill.

The group of calves consisted of five Ayrshires, three Holsteins and three Jerseys, both sexes being represented. These experimental subjects were from heifers and cows that received, during the terminal six to eight weeks of gestation, standard barn rations supplemented with pasture grazing at irregular intervals.

The dietary regimen of the calves was as indicated in table 1. The colostrum was withdrawn from the udder as completely as possible by standard procedures within six hours after parturition and thereafter at the regular morning and evening milking periods. Each calf was hand-fed the colostrum from its respective dam immediately after milking. Whole milk, testing from 3.7 to 4.0 percent fat, and separated milk were fed morning and evening at the daily rate indicated in table 1. The transition from whole milk to separated milk was made gradually from the fourth to the fifth week. All milk was from a herd that received an excellent ration consisting of a concentrate mixture and Atlas sorgo silage fed in the barn, high quality alfalfa hay provided *ad libitum* in a paddock and limited pasture herbage grazed several hours daily. After the calves were two weeks of age, they were given a simple concentrate mixture immediately following each milk feeding and were supplied with fair quality prairie hay and green leafy alfalfa hay at all times.

TABLE 1. FEEDS GIVEN TO EXPERIMENTAL CALVES DAILY

Age	Lacteal products fed		Concentrate mixture fed	Hays fed (Prairie and alfalfa)
	Kind	Rate of feeding		
days				
1– 3	Fresh colostrum	1-lb./10-lb. body wt.[2]	None	None
4–14	Whole milk[1]	1-lb./10-lb. body wt.[2]	None	None
15–28	Whole milk	1-lb./10-lb. body wt.[2]	To extent of appetite	Free access
29–35	Whole milk and separated milk	1-lb./10-lb. body wt.[2]	To extent of appetite	Free access
36–70	Separated milk	1-lb./10-lb. body wt.[2]	To extent of appetite	Free access

[1] Combined herd, Ayrshires, Holsteins, Guernseys and Jerseys, but predominately Holstein.
[2] Maximum quantity limited to 12 lb. daily.

Whenever weather conditions were favorable, the calves were released in an open paddock where water and common salt were accessible.

Samples of venous blood were collected from the respective calves before colostrum consumption, at one-day intervals during the first three postnatal days, at seven-day intervals from one to six weeks of age and at 14-day intervals thereafter to ten weeks of age. These samples were obtained from six to eight hours after the regular morning feeding. The serum of the blood was assayed for carotenoids and vitamin A by the Kimble (1939) procedure.

Results and Discussion

The data revealed a marked variability in the concentrations of vitamin A and carotenoids of the blood serum from the individual calves of the group but a similarity in the trends of these constituents. Though breed generally is considered to be a factor associated with differences in the levels of these vitamin A constituents, the individual variations within the breeds represented in this study were greater than the differences among the breeds. Therefore, the data from all calves at the respective chronological stages were included in the averages (figure 1). Indications of the degree of variability and the significance of the changes in the levels are shown by the vertical lines representing twice the standard error of the mean.

In accord with the observations of other workers (Hansen, Phillips and Rupel, 1946; Hansen, Phillips and Smith, 1946; Hibbs and Krauss, 1947; Lundquist and Phillips, 1943; Moore and Berry, 1944; Phillips *et al.*, 1941; Sutton and Kaeser, 1946) the concentrations of carotenoids and of vitamin A in the blood serum of calves from cows receiving a standard herd ration were low at birth but markedly increased after colostrum ingestion. During this colostral period, the vitamin A reached a maximum level the second day and the carotenoids either the third day or shortly thereafter. Since daily samples were not collected between the third and the seventh days, it is possible that the peak concentration might have been later than revealed by the curves (figure 1). Following the period of colostrum consumption, the carotenoid and the vitamin A content of the blood serum gradually declined until the fifth week, after which the levels increased. At the eighth week, the vitamin A curve tended to plateau between 14.0 and 14.5 γ/100 ml. of blood serum, which level was slightly lower than the peak for the colostral period; whereas the carotenoids continued to increase beyond the concentration attained during colostrum consumption. In general the trends in the concentrations of carotenoids and vitamin A paralleled, but the rates of change of the former were more pronounced than those of the latter. The variability of the concentrations of both constituents seemed to become greater as the levels increased in response to colostrum ingestion initially and to hay consumption subsequently. This marked variability might have been due to differences in intake and in metabolism.

The only clinical evidence of abnormality in the group of calves was the occurrence of several cases of pink-eye. Apparently neither the incidence nor the severity of this disease was related to the vitamin A content of the blood.

The carotenoids and the vitamin A content of the blood serum of the calves during the first ten-week postnatal period, though variable in individuals, showed definite trends for the group. Diet seemed to be the primary

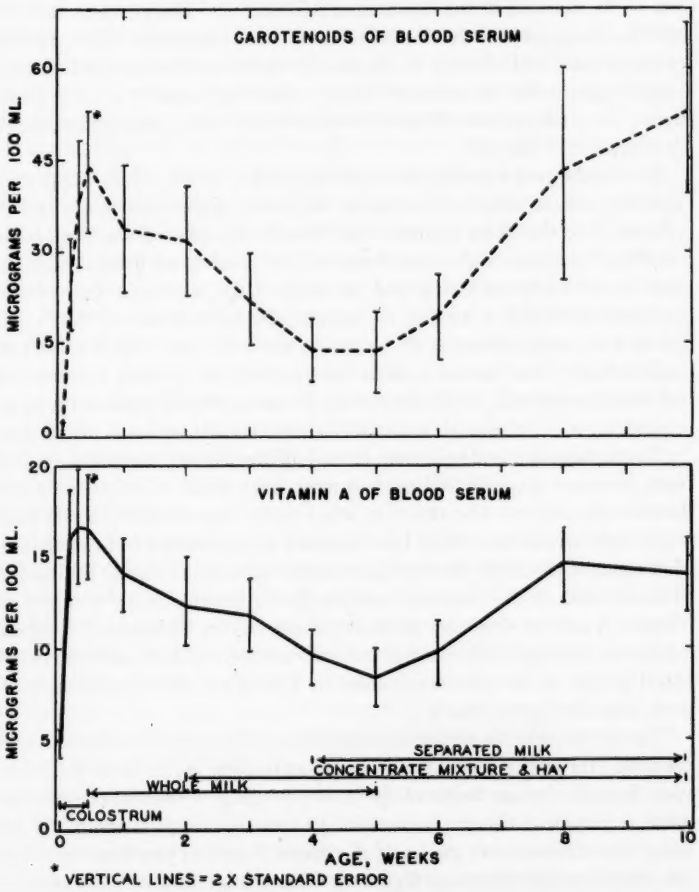

Figure 1. Relation of the changes in the diets of young calves to the level of carotenoids and vitamin A in the blood serum.

factor determining the levels in the blood, but it is probable that many less obvious factors played a supplementary role. The most striking dietary response was the abrupt rise following ingestion of colostrum. The wide ranges in concentrations of vitamin A and its precursor in the blood during this period may be ascribed primarily to extremes in the vitamin A potency of the colostrum ingested (Hansen, Phillips and Smith, 1946; Parrish *et al.*, 1947). An increase in the vitamin A content of the blood appears to be requi-

site to the survival of the neonatal calf (Moore and Berry, 1944), but the optimum magnitude of this increase has not been established. The quantity of carotenoids and vitamin A ingested in colostrum (Sutton and Kaeser, 1946) suggests that an excess of these nutriments normally is supplied to insure the establishment of hepatic reserves early in the postnatal stages of development of the calf.

During the post-colostral period of four to five weeks, while whole milk was the primary source of nutrients, the levels of the carotenoids and of vitamin A in the blood declined even though the milk fed was from cows receiving roughages high in carotenoids. The blood serum assays indicated that the calves between four and six weeks of age, were in a state of submarginal deficiency according to current standards (Boyer *et al.*, 1942; Loosli *et al.*, 1945; Moore *et al.*, 1943); yet there was no clinical evidence of malnutrition. This, however, does not preclude the possible existence of subclinical symptoms. If the low levels of vitamin A had persisted over an extended period, presumably avitaminosis A would have been manifested.

The feeding of mixed milk from several different breeds is not in harmony with practices generally followed in most dairy herds in which only one breed is represented. The extent to which restriction of calves to milk from their respective breeds would have modified the carotenoid and the vitamin A content of the blood was not determined. Since under similar feed conditions the milk of the Guernsey and the Jersey breeds usually is higher in vitamin A activity than that of the Ayrshires and the Holsteins, it is logical to assume that these differences in milk composition would be reflected in the blood picture of the calves consuming it. This phase of the problem, however, warrants further study.

The reduction of the carotenoid and vitamin A content of the blood serum continued three weeks after initiation of hay feeding. Apparently the calves were from five to six weeks of age before roughage consumption was adequate to provide sufficient carotenoids to veer the trends in the blood upward. The differences in the levels of vitamin A and its precursor spread as the concentrations increased (figure 1). This change in the relationship of these constituents conforms with the data presented by Moore and Berry (1945). The extreme variability during the latter stages apparently was due to the individual differences in rates of hay consumption. Unfortunately, no record of roughage intake was made.

Although the concentrations of vitamin A in the blood serum of calves from eight to ten weeks of age apparently were above the physiological minimum for summer conditions, the levels probably would be borderline for winter temperatures (Keener *et al.*, 1942; Moore *et al.*, 1943). Difficulty in meeting winter needs may be accentuated by the gradual reduction of

the quality of the hay. However, if low temperatures tend to stimulate the appetite, as generally believed, it is possible that increased intake during the winter months might compensate, in part, for the higher requirements. Irrespective of season, the results reported herein reemphasize the importance of supplying calves with palatable hay high in carotenoids.

The desirability of fortifying the calf ration during the first several weeks following birth is a practical feeding problem that is being investigated extensively. The decline (figure 1) from the maximum during the colostral period to the minimum before responding to hay consumption was approximately 45 percent for the carotenoids and 50 percent for vitamin A. These results, in accord with the findings of others (Moore and Berry, 1944. 1945; Nelson *et al.*, 1944), suggest a possible need for supplementation during the five or six weeks following colostrum feeding. Additional vitamin A in the diet of the calf during its early stages of postnatal development increases the concentration of this vitamin in the blood (Sutton and Kaeser, 1946; Hibbs and Krauss, 1947) and in the liver (Hibbs and Krauss, 1947). Since no advantage from this supplementation was demonstrated in the general well-being of the calves on a good, standard dietary regimen (Hibbs and Krauss, 1947; Nevens and Kendall, 1947; Norton *et al.*, 1946), the nutritional value of additional stores of vitamin A has been considered doubtful.

If the low concentration of vitamin A in the blood serum may be regarded as an index of liver reserves (Braum, 1945; Hibbs and Krauss, 1947; Lewis and Wilson, 1945), the stores were being reduced over a period of several weeks. Though the depletion was not accompanied by symptoms of malnutrition, diminution of the quantity of vitamin A in the body of the calf during the early stages of postnatal life seems to be inconsistent with good nutrition. In concurrence with the viewpoint of Lewis and Wilson (1945), it appears desirable to supply the calf with sufficient vitamin A and/or carotenoids to permit at least a moderate degree of storage throughout the first few weeks after birth. Colostrum, except in rare instances, seems to provide adequate quantities of vitamin A for the neonatal calf; therefore, in order to avoid the marked subsequent decline in the levels of these vitamin A constituents in the blood, it would seem advisable to fortify the calf ration during the period from colostrum consumption to effective hay intake.

Summary

The concentrations of carotenoids and of vitamin A in the blood serum of calves, subjected to standard herd dietary and managerial practices, from birth to ten weeks of age were closely related to the changes in the types of feeds consumed.

Though there was a marked degree of variability in the concentrations of

carotenoids and of vitamin A in the blood serum of individuals of the group, the general trends in the levels of these constituents in each calf were similar.

Colostrum ingested at the rate of one pound *per* ten pounds of body weight daily effected a striking increase of carotenoids and of vitamin A in the blood of the new-born calf.

Whole milk fed to the calves at the same rate as the colostrum, to a maximum of 12 pounds daily, even when produced by cows receiving high quality roughage including some pasture herbage, did not provide sufficient vitamin A activity to prevent a continuous decline in the concentration of carotenoids and of vitamin A in blood serum to levels in the deficiency range.

Though good quality hay was accessible to the calves after two weeks of age, they were six weeks of age before the intake of carotenoids from this source was sufficient to increase the carotenoid and the vitamin A content of the blood.

The marked reduction of these constituents in the blood during the interim between colostrum ingestion and effective hay consumption indicated a need for vitamin A supplementation during this period and further emphasized the importance of feeding palatable hay high in carotene.

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PANTOTHENIC ACID STUDIES WITH THE HORSE

P. B. Pearson and H. Schmidt[1]
Agricultural and Mechanical College of Texas

INVESTIGATIONS on the role of the various B vitamins in the nutrition of Equidae have not been commensurate with the work and information available for other species of domestic animals. In fact, there is no information on the quantitative requirements of the horse for many of the B vitamins and for several it is not even known whether or not they are dietary essentials. The horse being a monogastric herbivorous animal could be expected to differ from ruminants with respect to their dietary requirements for the B vitamins.

There is good evidence that some of the B vitamins are dietary essentials for the horse. Naito *et al.*, (1925) and Carlström and Hjärre (1939) reported that horses fed rations deficient in the B vitamins became emaciated, developed anorexia and incoordination of movements. It has been estimated by Pearson, Sheybani and Schmidt (1944*a*, 1944*b*) that 44 μg. of riboflavin per kg. of body weight daily meets the requirements of the horse for this vitamin. It has recently been suggested by Jones *et al.*, (1945) that iridocyclitis or periodic ophthalmia may be due to a deficiency of riboflavin.

Evidence has been presented indicating that nicotinic acid is synthesized by the horse and may not be a dietary essential for this species (Pearson and Luecke, 1945*a*; and Huff, Pearson and Perlzweig, 1946). Since it has recently been shown that dietary tryptophane can be converted to nicotinic acid (Schweigert, Pearson and Wilkening, 1947) it would be expected that the need of the horse for a dietary source of this vitamin is influenced by the amount of tryptophane in the diet.

For the past 5 years studies have been in progress at this institution on the metabolism and nutritional requirements of the horse for various members of the B group of vitamins. Considerable information has been obtained on pantothenic acid including data on renal excretion, its possible importance in practical rations for horses and other pertinent information. While the quantitative requirements of the horse for this vitamin have not been established we do have data on levels that allow for a good state of health and satisfactory growth. This together with other pertinent information are presented in this paper.

Experimental

The animals used in these studies were registered Shetland ponies. Considering the cost of ingredients for more or less purified diets the economical

[1] The authors are indebted to Merck & Company for the calcium pantothenate, and to the F. E. Booth Company for the A and D oil used in these investigations.

advantages of using a small breed is readily apparent. Male animals only were used as they are more suitable than females for the collection of urine. A total of 22 animals have been used in these studies. Most of the ponies were about 9 months of age at the beginning of the experiment. They were housed in individual box stalls and a daily record kept of the feed consumed. At intervals of 3 or 4 times a week they were turned out in a paddock to exercise. A specially designed muzzle was used to prevent the animals getting any feed while out of doors. Weights were taken at weekly intervals. The urine was collected quantitatively by means of a specially designed cage which excluded any contamination from feces. The urine was collected once each month for two consecutive 24-hour periods. The pantothenic acid in the urine was determined microbiologically by the method of Neal and Strong (1943) and the assays on the components of the rations were made by the same method with the modification introduced by Pearson and Luecke (1945*b*).

The experimental rations were made up of dried beet pulp, yellow corn, casein, dicalcium phosphate and vitamin supplements. The percentage composition of the major components of the basal ration used most of the time were dried beet pulp 58, ground yellow corn 31, casein 10 and dicalcium phosphate 1. This ration was supplemented with a high potency A and D oil, riboflavin and salt (NaCl) fed *ad libitum*. This basal ration was supplemented with varying levels of calcium pantothenate ranging from none up to 6.6 mg. per kg. of ration. The pantothenic acid content of the basal ration was 3.3 mg. per kg. This is considerably lower in pantothenic acid than would occur with any common combination of feeds normally fed to horses in this country. The total pantothenic acid content of the rations was calculated by adding to the amount in the basal ration the different levels of synthetic calcium pantothenate added. On this basis the levels of pantothenic acid expressed in mg. per kg. of feed were for the different rations 3.2, 4.3, 5.4, 6.5 and 9.8.

The daily intake of pantothenic acid expressed in μg per kg. of body weight ranged from approximately 38 to 150 (see figure 1 for exact levels). The lower levels are considerably below the requirements for species for which this vitamin is a dietary essential. Hughes and Ittner (1942) reported that the requirement of the pig for pantothenic acid lies between 170 and 235 μg. per kg. of body weight daily. The requirement for the dog appears to be somewhat less than 100 μg. per kg. of body weight daily (Schafer, McKibbin and Elvehjem, 1942).

The horses were kept on the experimental rations for periods ranging from 6 months to more than a year. Growth and the urinary excretion of pantothenic acid have been used as the two main criteria of the performance of the animals on the different dietary regimens.

At various times during the course of these investigations some of the ponies suffered from diarrhea. Since this is one of the manifestations of a pantothenic acid deficiency in swine (Wintrobe *et al.*, 1943) we were inclined to think at first that the condition in the ponies might be associated with an inadequate intake of this factor. Later as the data became more extensive with higher and lower levels of pantothenic acid it was apparent that there

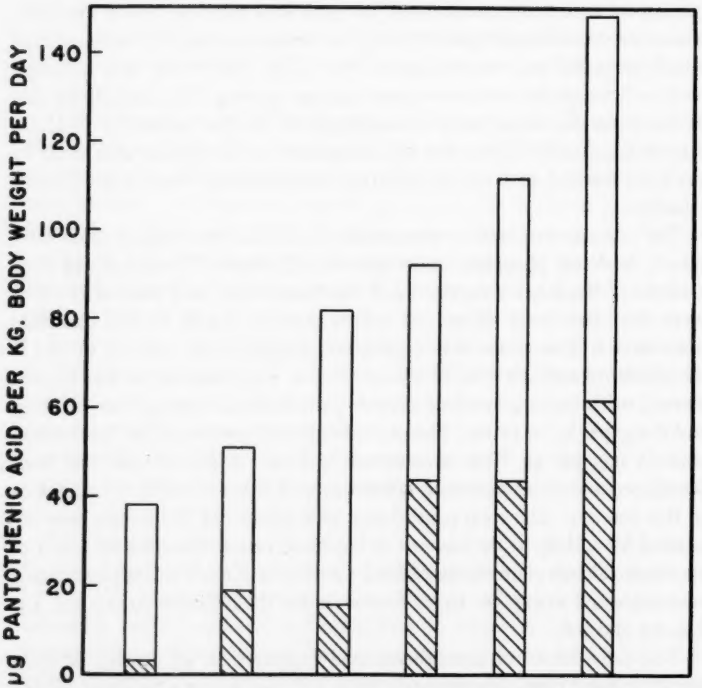

Figure 1. The effect of the amount of pantothenic acid ingested on the amount excreted by the renal pathway. The μg. of pantothenic acid ingested daily per kg. of body weight is indicated by the height of the column and the shaded portion represents the excretion by the renal pathway.

was no consistent relationship between the incidence of diarrhea in the ponies and the levels of pantothenic acid in the ration. The incidence of the diarrhea was much higher in some years than others and we are now inclined to believe that it was due to either a lack of unidentified factors or to physical properties of the ration.

Growth

Normally horses are not fed for maximum rates of gain such as animals produced for meat purposes under feed lot conditions. Furthermore, the Shetland pony is a rather slow growing breed. These facts together with the limited number of animals vitiates to a certain extent the use of growth as a satisfactory criterion of the nutritional significance of the different levels of pantothenic acid.

On none of the levels of pantothenic acid was there apparent retardation of growth. The differences in the rate of increase in body weight was no greater between the animals of different levels of pantothenic acid than among the ponies on the same level of pantothenic acid intake. The ponies with an intake of pantothenic acid of approximately 38 μg. per kg. of body weight daily made satisfactory gains not significantly different from the ponies on the higher levels. The data indicate that under the conditions of these experiments the pantothenic acid requirement of horses (Shetland ponies) was satisfied by an intake of approximately 38 μg. per kg. of body weight daily or by a ration containing 3.2 mg. of pantothenic acid per kg. of feed.

Urinary Excretion of Pantothenic Acid

The data on the relationship of the level of pantothenic acid ingested to the amount excreted are summarized in figure 1. The data in figure 1 represent those obtained from ponies that were on each dietary regimen for not less than 6 months. The computations are based on the intake and urinary excretion of pantothenic acid during the last 3 months of each dietary treatment. The intake and output of pantothenic acid expressed in μg. per kg. of body weight daily was calculated for each individual horse and the average taken for all the ponies on each level.

The amount of pantothenic acid excreted is definitely influenced by the amount ingested. The ponies ingesting about 150 μg. of pantothenic acid daily per kg. of body weight excreted by the renal pathway approximately 62 mg. of pantothenic acid per kg. of body weight. When the intake of pantothenic acid was 38 μg. daily per kg. of body weight the urinary excretion declined to about 3 μg. daily per kg. of body weight.

There was a tendency for the percentage of the ingested pantothenic acid that was recovered in the urine to decrease with the lower levels of intake. Thus with an intake of 150 μg. daily per kg. of body weight 41 percent was excreted in the urine whereas at the 38 μg. level of intake only 12.7 percent was recovered in the urine. This indicates that synthetic pantothenic acid administered per os is utilized by the horse. The percentage of ingested pantothenic acid recovered in the urine of the horse is of the same order as the

amount excreted by rabbits. The administration of 400 mg. of calcium pantothenate to a rabbit was followed by the recovery of 52 percent in the urine within a 24-hour period (Pearson, 1941).

The horse and rabbit have certain similarities in that they are each herbivorous, are monogastric and have a large cecum. The role of the cecum of these species in microbiol synthesis remains to be determined, but it would not be surprising if there is considerable synthesis of some of the B vitamins in the gastro-intestinal tract. Evidence to support this is the observation based on balance studies that rabbits synthesize appreciable amounts of pantothenic acid and riboflavin (Olcese and Pearson, 1947).

During the first two years of these studies samples of blood obtained at regular intervals were assayed for pantothenic acid. Within the range of the levels of pantothenic acid ingested the levels in the blood did not appear to bear a consistent relationship to the dietary intake. For this reason the detailed data on the blood are omitted to conserve space. There was considerable variation in the pantothenic acid values. The average was 21.3 μg. per 100 ml. of whole blood.

Summary

On the basis of studies with Shetland ponies it appears that a daily intake of 38 μg. of pantothenic acid per kg. of body weight is adequate to permit normal growth and health in the horse.

The amount of pantothenic acid excreted by the renal pathway is influenced by the levels ingested. On the level of 150 μg. daily per kg. of body weight 41 per cent was excreted in the urine whereas when the level ingested was 38 μg. per kg. of body weight only 12.7 percent was excreted by the renal pathway.

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EFFECTS OF THYROPROTEIN AND OF THIOURACIL ALONE AND IN SEQUENCE IN THE RATION OF SWINE[1]

GEORGE W. VANDER NOOT, RALPH P. REECE AND WILLIAM C. SKELLEY
New Jersey Agricultural Experiment Station

ECONOMICAL meat production depends upon the rapid growth and fattening of meat animals. Since the thyroidal hormone is intimately concerned in these processes, investigators have attempted, by various techniques, to alter the amount of circulating thyroidal hormone in a number of species. There is some evidence that a mild hyperthyroid condition may be conducive to rapid growth. Koger, Hurst, and Turner (1942) showed that thyroxine-injected mice gained an average of 28 percent more weight during a period of five weeks than did the controls. Mice receiving thyroprotein gained from 16 to 23 percent more in weight and an average of 28 percent more in length than did untreated controls (Koger, Reineke, and Turner, 1943). For a short period of time the growth rate of male guinea pigs was slightly accelerated by the inclusion of a small amount of thyroprotein in their ration (Koger and Turner, 1943). Reineke and McMillen (1946) reported that Berkshire pigs receiving a ration containing from 0.005 to 0.0075 percent thyroprotein gained slightly more than did the controls and required slightly less feed per unit of gain during an eight-week feeding period. Braude (1947), however, was unable to increase the rate of growth of pigs by thyroprotein feeding. The daily doses per pig varied from 0.25 to 1.5 grams, and while the higher doses adversely affected the rate of growth of pigs, the smaller doses were not sufficiently effective to be of any practical importance. There is some indirect evidence that an active thyroid state is associated with rapid growth. The thyrotrophic content of the anterior lobe of the pituitary gland is highest during the period of rapid growth in cattle (Reece and Turner, 1937), in rats (Turner and Cupps, 1939), in rabbits (Bergman and Turner, 1941), and in swine (Elijah and Turner, 1942). In addition, the pituitaries of slow-growing strains of swine have been reported to be lower in thyrotrophic potency than those of more rapidly growing strains (Elijah and Turner, 1942).

Although an active thyroid condition appears to exist during the growing period, a lowering of thyroid function is conducive to the fattening process. Kempster and Turner (1945) found that the feeding of a ration containing 0.2 percent thiouracil to New Hampshire chicks for 36 days improved the carcass grade but reduced the rate of growth and increased the amount of

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feed required to produce a pound of gain in weight. Andrews and Schnetzler (1946) found that when thiouracil was fed at a level of 0.20 percent to Barred Plymouth Rocks between the 6th and 14th weeks, growth was slightly retarded but market grade and fat deposition were significantly increased. Muhrer and Hogan (1945) pair-fed four groups of swine identically except for the addition of 0.2 percent of thiouracil to the ration of the experimental animals. After 28 days, the experimental animals were shorter and fatter and had gained weight more rapidly and economically than had the controls McMillen, Reineke, and Bratzler (1946) found that Chester White barrows averaging 162 pounds and fed ad libitum on a ration containing 0.1 percent thiouracil for 41 days made 0.16 of a pound less daily gain than did the controls. The experimental pigs, however, required 14 percent less feed per unit of gain. Five Yorkshire pigs fed thiouracil made gains almost equal to that of the controls and required 19 percent less feed per unit of gain. Vander Noot, Reece and Skelley (1947) reported that hogs self-fed a ration containing 0.25 percent thiouracil consumed 27.5 percent less feed per 100 pounds gain in body weight than did hogs self-fed the same ration but containing no thiouracil. The thiouracil-fed hogs made an average daily gain of 1.60 pounds, whereas the control hogs gained 1.23 pounds per day. Feeding lambs 0.175 to 0.544 grams of thiouracil daily per lamb had no significant effect on the rate of growth (Andrews *et al.*, 1947). Significant reductions in lamb growth occurred when thiourea was fed at levels ranging from 0.048 to 0.071 grams per lamb per day. Beeson, Andrews and Brown (1947) reported that the feed consumption of steers was not influenced by 2.0 and 6.0 grams of thiouracil fed daily, but the rate of gain was slightly increased in the groups receiving 2.0 and 4.0 grams of thiouracil daily.

The purpose of our investigation was to determine the effect of (1) feeding various levels of thyroprotein to weanling pigs; (2) feeding thyroprotein from weaning to approximately 125 pounds and finishing on a ration containing thiouracil; and (3) feeding a ration containing thiouracil from weaning to a finish weight.

Materials and Methods

Purebred Duroc Jersey and Berkshire pigs were used throughout the trials. A ration containing 75 percent yellow dent corn, 7 percent alfalfa leaf meal, 7 percent meat scraps, 9 percent soybean meal, and 2 percent minerals was fed. The first trials were run during the summer and winter of 1945 respectively.

Seven lots of pigs, 3 of 8 each and 4 of 6 each, were hand-fed from 0.075 gram to 4.0 grams of thyroprotein[2] per 100 pounds of liveweight in their

[2] The thyroprotein (Protamone) was kindly furnished by the Cerophyl Laboratories, Inc., Kansas City, Missouri, through the courtesy of Dr. W. R. Graham, Jr.

daily ration. The pigs were weighed weekly to determine the grams of thyroprotein they were to receive the ensuing week. Each week 7 pounds of feed were weighed separately for each lot receiving the thyroprotein, the adjusted amount of thyroprotein was incorporated, and each lot fed daily one pound of the mixture as part of its ration. Two lots of pigs received the basal ration only and served as controls.

In a second trial, 8 weanling pigs were self-fed a ration containing 0.1 percent of thyroprotein until they attained an average weight of approximately 125 pounds in the summer of 1946. Thyroprotein feeding was discontinued, and a ration containing 0.25 percent thiouracil[3] was self-fed until the pigs reached a marketable weight. A lot of 8 weanling pigs received the basal ration only and served as controls.

In the third experiment, 8 weanling pigs were self-fed a ration containing 0.25 percent of thiouracil during the winter of 1946. It was planned that these pigs should be kept until they attained a marketable weight, but growth was retarded to such a degree that this proved undesirable. A pen of 8 weanling pigs received the basal ration only and served as controls. Two of the experimental hogs were maintained on the ration containing thiouracil until the time of slaughter; two were slaughtered 5 days after the thiouracil had been removed from the ration, 2 were slaughtered 7 days after, and 2 were slaughtered 8 days after the removal of thiouracil from the ration. A thyroid gland from a control hog and six glands from the thiouracil-fed hogs were removed and weighed. At the time of slaughter, blood and liver were collected from the thiouracil-fed hogs. The blood was air-dried at room temperature by means of an electric fan. The liver was run through a food grinder, spread on glass plates, and dried in an oven at a temperature of 60° C. The dried liver was ground finely with a food grinder, and the dried blood was powdered in a ball mill. To test for the presence of thiouracil, groups of albino rats, consisting of 5 rats per group, were fed the equivalent either of 10 ml. of fresh blood or 10 grams of fresh liver daily for 14 days. On the fifteenth day the rats were killed, their thyroid gland removed, dissected, and weighed. A group of stock rats receiving a stock diet only served as controls.

Results and Discussion

Influence of various levels of thyroprotein on weight gains and feed consumption of weanling pigs:

Feeding 0.075, 0.15, and 0.225 grams of thyroprotein per 100 pounds of body weight for 63 days had no influence on gains in weight, but pigs receiving the 0.225 gram required slightly more feed per 100 pounds gain in

[3] The thiouracil (Deravet) was kindly furnished by the Lederele Laboratories, Pearl River, New York, through the courtesy of Dr. Mark Welsh.

weight than did the control pigs. Higher levels of thyroprotein feeding, 0.5, 1.0, 2.0, and 4.0 grams per 100 pounds of body weight, for 64 days resulted in a decrease in the average daily gain in body weight and an increase in the amount of feed consumed per 100 pounds of gain in body weight. The control pigs gained 1.30 pounds per day, whereas the pigs receiving 4.0 grams of thyroprotein daily per 100 pounds of liveweight gained only 0.62 of a pound per day. The control pigs required 287.7 pounds of feed per 100 pounds of gain in body weight, but the pigs fed the highest level of thyroprotein required 416.8 pounds of feed. These results are summarized in table 1.

TABLE 1. EFFECTS OF VARIOUS LEVELS OF THYROPROTEIN ON THE WEIGHT GAINS AND FEED CONSUMPTION OF WEANLING PIGS

	No. of pigs	Days on trial	Avg. initial weight	Avg. final weight	Avg. gain in weight	Avg. daily gain	Feed consumed per 100 lb. of gain
			lbs.	lbs.	lbs.	lbs.	lbs.
Control	8	63	47.6	133.3	85.7	1.36	278.4
Fed 0.075 gm. per cwt. of liveweight	8	63	47.6	136.4	88.8	1.41	280.8
Fed 0.15 gm. per cwt. of liveweight	8	63	47.6	133.1	85.5	1.36	281.2
Fed 0.225 gm. per cwt. of liveweight	8	63	47.6	131.9	84.3	1.34	292.9
Control	6	64	40.2	123.2	83.0	1.30	287.7
Fed 0.5 gm. per cwt. of liveweight	6	64	40.2	92.0	51.8	0.81	315.7
Fed 1 gm. per cwt. of liveweight	6	64	40.8	101.9	61.1	0.95	347.1
Fed 2 gm. per cwt. of liveweight	5*	64	40.0	88.6	47.8	0.75	463.2
Fed 4 gm. per cwt. of liveweight	6	64	39.8	79.3	39.5	0.62	416.8

* One pig died; calculations adjusted to five animals.

Effect of feeding thyroprotein from weaning to approximately 125 pounds and finishing on a ration containing thiouracil:

Eight weanling pigs fed a ration containing 0.1 percent thyroprotein required 87 days to reach an average weight of 129 pounds, whereas 8 weanling pigs fed the basal ration only attained an average weight of 125 pounds in 68 days. Moreover, the control pigs were more efficient utilizers of feed, consuming 322.1 pounds of feed per 100 pounds of gain as compared with 449.5 pounds consumed by the thyroprotein-fed pigs. Withdrawal of thyro-

protein from the ration and the feeding of a ration containing 0.25 percent thiouracil enabled the experimental pigs to gain as rapidly as did the control pigs. In addition, inclusion of thiouracil in the ration resulted in more efficient utilization of feed by the experimental pigs; the thiouracil group required 395.7 pounds and the control group required 406.9 pounds of feed for each 100 pounds gain in weight. Table 2 presents a summary of these results.

TABLE 2. EFFECT OF FEEDING THYROPROTEIN FROM WEANING TO APPROXIMATELY 125 POUNDS AND FINISHING ON THIOURACIL

Treatment	No. of pigs	Days on trial	Avg. initial weight	Avg. final weight	Avg. gain weight	Avg. daily gain	Feed consumed per 100 lb. of gain
			lbs.	lbs.	lbs.	lbs.	lbs.
Control	8[1]	68	36.7	125.0	88.3	1.30	322.1
0.1% thyroprotein	8[2]	87	36.8	129.0	92.2	1.06	449.5
Control	8[1]	42	125.0	202.8	77.8	1.90	406.9
0.25% thiouracil	8[2]	40	129.0	202.1	73.1	1.80	395.7

[1] Same group of pigs.
[2] Same group pf pigs.

Effect of feeding a ration containing thiouracil from weaning to a finish weight.

Eight weanling pigs received a ration containing 0.25 percent of thiouracil for 97 days and 8 other weanling pigs received the basal ration only for 97 days. The pigs fed thiouracil gained rapidly in weight in the beginning but stopped growing in frame structure. They were very inactive, reluctant to eat, and in general were rather listless. The control pigs made an average daily gain of 1.67 pounds, whereas the thiouracil-fed pigs made an average daily gain of only 0.57 of a pound. The thiouracil-fed pigs, however, consumed less feed per 100 pound of gain than did the control pigs, 340 pounds compared with 367 pounds. At the termination of the trial, the experimental pigs were short and fat and contrasted markedly with the control pigs (figure 1). These results are summarized in table 3.

Feeding of thiouracil cased a marked increase in the weight of the thyroid gland. The thyroid gland from one control pig weighed 9.6 grams, whereas the thyroid glands from 6 thiouracil-fed pigs averaged 46.7 grams (range 21.9 to 94.9).

There was an insufficient amount of thiouracil in either the blood or the liver of thiouracil-fed pigs to induce an increase in the thyroid weight of rats each fed the equivalent of either 10 ml. of fresh blood or 10 grams of fresh liver daily for 14 days. The thyroid glands from the control rats aver-

TABLE 3. EFFECT OF 0.25 PERCENT THIOURACIL ON WEIGHT GAINS AND FEED CONSUMPTION OF WEANLING PIGS

	No. of pigs	Days on trial	Avg. initial weight	Av.g final weight	Avg. gain weight	Avg. daily gain	Feed consumed per 100 lbs. gain
			lbs.	lbs.	lbs.	lbs.	lbs.
Control	8	97	41.1	204.0	162.9	1.67	367.1
Fed 0.25% thiouracil	8	97	41.0	96.1	55.1	0.57	340.1

aged 15.2 mg. The thyroid glands from the rats fed blood and liver of pigs kept on thiouracil until the time of slaughter averaged 14.0 and 17.8 mg. respectively. The thyroid glands from the rats fed blood and liver of pigs slaughtered 5 days after the thiouracil had been removed from the ration averaged 13.3 and 14.5 mg. respectively. No attempt was made to test the blood and liver of experimental pigs that were slaughtered 7 and 8 days after the withdrawal of thiouracil from the ration, since the first tests were negative.

Although a number of different levels of thyroprotein were tried, none was found that would increase the gains in weight of the pigs. The lower levels had no influence on either gains in weight or amount of feed required

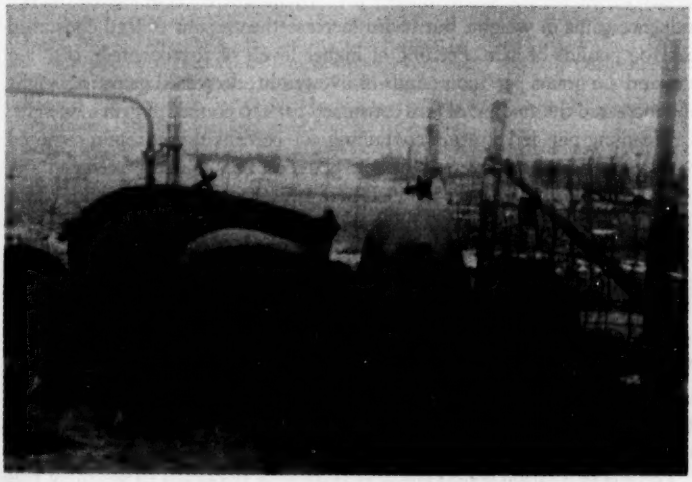

Figure 1. Thiouracil fed pigs and two of the controls, marked X, after 97 days of feeding.

to produce an increase of 100 pounds in weight. On the other hand, the higher levels of thyroprotein decreased the gains in body weight and increased the feed consumption per 100 pounds gain in weight. In the growing pig it would appear that nothing is to be gained by increasing its basal metabolic rate.

The purpose of the second trail was not attained, since the amount of thyroprotein fed proved to be excessive. If, however, one could find a level of thyroprotein that would increase the rate of skeletal development, then it should be advantageous to feed a ration containing thiouracil during the finishing period.

As was to be expected, inclusion of thiouracil in the ration of weanling pigs greatly retarded their growth. It would appear, therefore, that thiouracil should not be fed to pigs until they have reached the desired development of their skeleton.

Additional evidence is desirable, but on the basis of preliminary test it is not likely that thiouracil is present in thiouracil-fed pigs in sufficient amounts to influence the consumer.

Summary and Conclusions

Daily feeding of either 0.075 or 0.15 of a gram of thyroprotein per 100 pounds of liveweight had no influence on gains in body weight or the amount of feed consumed per 100 pounds of gain. Feeding of 0.225 of a gram did not influence gains in weight, but it did increase the amount of feed consumed per 100 pounds of gain. Feeding of higher levels of thyroprotein, 0.5, 1.0 2.0, and 4.0 grams per 100 pounds of liveweight, decreased gains in weight and increased the amount of feed consumed per 100 pounds of gain in weight.

Weanling pigs fed a ration containing 0.1 percent thyroprotein required 87 days to weigh an average of 129 pounds. The controls averaged 125 pounds in 68 days and were more efficient utilizers of feed, consuming 322.1 pounds compared to 449.5 pounds consumed by the experimental group for each 100 pounds of liveweight gained. The controls had an average daily gain in eight of 1.30 pounds, and the thyroprotein-fed pigs gained an average of 1.06 pounds daily.

However, when 0.25 percent thiouracil was substituted for the thyroprotein in the ration of the experimental group, the average daily gain was 1.8 pounds compared to 1.9 pounds for the controls. The feed consumed for 100 pound of gain in weight was 395.7 pounds for the experimental group and 406.9 pounds for the control pigs.

Feeding of a ration containing 0.25 percent of thiouracil to weanling pigs for 97 days resulted in an average daily gain of 0.57 of a pound as compared with 1.67 pounds for control pigs. The amount of feed consumed per 100

pounds of gain by the thiouracil-fed pigs was 340.1 pounds as compared with 367.1 pounds for the control pigs.

The principal conclusions drawn from these studies are summarized as follows: (1) Low levels of thyroprotein fed to pigs had no influence on either gains in weight or amount of feed required to produce an increase of 100 pounds in weight. (2) Higher levels of thyroprotein decreased gains in weight and increased the feed consumption per 100 pounds gain in weight. (3) Thiouracil should not be fed to pigs until they have reached the desired development of skeletal growth. (4) The feeding of 0.25 percent of thiouracil in the ration will increase average daily gains and reduce the amount of feed consumed, after the desired skeletal growth has been obtained.

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THE COMPARATIVE EFFICIENCY OF BRED AND OPEN SOWS WHEN FATTENED AND SLAUGHTERED[1]

LESLIE E. JOHNSON AND TURNER WRIGHT
South Dakota Agricultural Experiment Station

THROUGHOUT large portions of the swine producing area in the corn belt it is a common practice to fatten and market sows following the weaning of their first or second litter. Many producers practice breeding the sows while in the feed lot as they believe this results in both faster and more economical gains. Packers, in general, disapprove of this procedure and believe that both packer and producer lose from this practice.

No experimental work on this problem with swine has been published to date. Cole and Hart (1937) found that pregnancy in rats increased skeletal and tissue growth over that of non-bred litter mates. This increased growth rate was accomplished by and dependent upon increased food consumption. Hart, Guilbert and Cole (1940) compared open and bred heifers in the feed lot and concluded that pregnancy did not increase food consumption or affect the economy of gain when the weight of the gravid uterus (which was mostly water) was considered. They also reported that pregnancy had little, if any, effect upon the grade of carcass or dressing percentage as long as the heifers were fairly well finished and had not been bred more than five or six months.

Materials and Methods

The sows used in this research study were composed of purebreds, high grades and crossbreds. All individuals were healthy and vigorous, and graded from medium to good in type and quality. They were divided into similar groups of ten head each on the basis of weight, breed, type, origin, and condition and placed in the feed lots immediately following the weaning of spring litters (late June and early July). The lot 1 sows were hand-bred as they came in heat. The lot 2 sows were left open.

Both groups were fed and managed alike throughout the tests. The ration consisted of shelled yellow corn, self-fed; ½ pound of protein supplement per head daily, hand-fed; mineral, self-fed; plus oats-rape pasture. The protein supplement was a mixture of equal parts of tankage, soybean oil meal, and linseed meal.

The sows were all marketed at one time directly to the packer. The buyer had no information concerning which sows were bred and which were open

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but he did know that the efficiency of bred and open sows was being studied. The same procedure was followed in collecting all carcass data.

In making the financial comparisons, no charge was made for the breeding of the sows. The tests were conducted for three consecutive years, 1943–45 inclusive. The length of feeding periods was 68 days, 54 days, and 61 days, respectively.

Experimental Results and Discussion

Results

During the first test an acute attack of necro occurred in both the bred and open lots. Two of the bred sows died and a third became so weak she had to be removed from the experiment. One abortion also occurred during the latter part of the feeding period in the bred lot. The sow showed a positive test for *Brucella abortus suis*. The effect of these diseases on the two lots of sows could not be accurately assessed. The extreme variation, relatively poor performance, and death losses indicate that both groups were affected and that they were probably affected to different degrees. For these reasons, the feed lot and carcass data are reported on only the last two years' work (tables 1, 2, and 3). However, in table 4, market and pregnancy data are reported on all three years' work. This seemed logical since the sows were very representative in condition and preganacy of those that buyers and packers handle regularly.

The data were summarized both by lots and by the criterion of being bred or open. It appears that the lot comparisons are the most reliable for determining the advisability of adopting the practice of breeding sows while fattening. The effects of breeding sows in the feed lot, however, are more clearly shown by comparing only bred with only open individuals. This was done in table 3. In the 1944 and 1945 tests, 85 percent of the sows in the bred lots carried pigs at the time of slaughtering.

Table 1 shows the production efficiency of the bred and open sows in the feed lot. The bred sows consumed 5.9 percent more feed daily; made 13.4 percent more gains daily, 0.26 pounds; and consumed 6.4 percent less feed per pound of gain than the open sows. The finished condition of the two lots of sows at the time of slaughter was very similar. This was also true for shrink enroute to market. The lot of open sows, however, outsold the bred sows by $0.34 per 100 pounds. The higher selling price and the slightly reduced shrink to market for the open sows more than cancelled the advantage of reduced feed cost in the bred lot. This resulted in the bred sows returning 3.9 percent, $0.23 per head less than the open sows. This amount, however, was not statistically significant. In arriving at the prices paid for the sows

TABLE 1. THE EFFICIENCY OF BRED AND OPEN SOWS IN THE FEED LOT, 1944 AND 1945 TRIALS. SOWS WERE FED FOR AN AVERAGE OF 57.5 DAYS

Items compared	Lot 1, bred	Lot 2, open
Number of sows (total)	20	20
Initial weight[1]	266.0	266.2
Final weight	392.4	378.0
Daily gain per sow	2.20	1.94
Feed per 100 pounds gain		
Corn	438.5	467.9
Protein supplement	22.3	24.7
Mineral	1.34	1.12
Feed Cost per 100 pounds gain[2]	$ 8.98	$ 9.61
Finished condition of sows	Good+	Good+
Shrink to market	8.0	6.5
Selling price per cwt. (No dockage other than in price)	$13.10	$13.44
Net returns per head[3]	$ 5.68	$ 5.91

[1] All weights in pounds.

[2] Feed prices: corn $1.05 for 56 pounds shelled; tankage $4.12 cwt; soybean oil meal $3.03 cwt; linseed meal $2.69 cwt; mineral $1.97 cwt.

[3] Labor, equipment costs, cost of breeding sows, and credit for manure are not included.

TABLE 2. SLAUGHTER AND CARCASS DATA ON BRED AND OPEN SOWS 1944 AND 1945 TRIALS. SOWS FED AN AVERAGE OF 57.5 DAYS. 17 BRED SOWS IN LOT 1 CARRIED PIGS AN AVERAGE OF 55.8 DAYS

Items compared	Lot 1, bred	Lot 2, open
Number of sows (total)	20	20
Weight at slaughter	384.4	371.5
Dressing %	77.6	78.7
Dressing % after docking	80.6	79.7
Thickness of fatback (inches)	2.20	2.24
Firmness of carcass[1]	Low firm	Firm
Yield of belly (% carcass weight)	19.1	19.0
Grade of belly[2]	Low medium	Low good

[1] Firmness of carcass scores: firm, medium, fair, soft.

[2] Grade of belly scores: good, medium, fair poor.

which appeared "piggy," the buyer estimated the dockage necessary to equalize the dressing percentage of "piggy" and "non-piggy" sows and fixed the price accordingly. Thus both price and amount of dockage in pounds were available for study, although all sows were purchased on the basis of price per hundred pounds of live weight.

The amounts of feed necessary per hundred-weight gain for the open and bred sows were 493.7 and 502.7, respectively, when the bred sows were docked for all uterus weight in excess of that of open sows. The amounts of

TABLE 3. COMPARISON OF FEED LOT AND SLAUGHTER DATA OF BRED AND OPEN SOWS BY LOTS AND BY BEING ACTUALLY BRED AND OPEN. 1944 AND 1945 TRIALS

Items compared	Bred lot	Open lot	Difference	Actually bred	Actually open	Difference
Number of sows (total)	20	20		17	23	
Daily gain per sow	2.20	1.94	.26*	2.24	1.94	.30*
Daily gain minus uterus and contents	1.99	1.91	.08	2.00	1.91	.09
Shrink to market	8.0	6.5	1.5	8.2	6.6	1.6
Selling price	13.10	13.44	.34**	13.06	13.42	.36**
Dressing %	77.6	78.7	1.1	76.9	79.0	2.1*
Dressing % after docking	80.6	79.7	.9	80.2	80.1	.1
Thickness of fatback	2.20	2.24	.04	2.17	2.25	.08
Firmness of carcass	2.8	3.7	.9**	2.6	3.7	1.1*
Yield of belly	19.1	19.0	.1	19.1	19.0	.1
Grade of belly	5.8	8.6	2.8**	5.4	8.6	3.2**
Weight of uterus and contents	12.2	2.0	10.2**	14.0	2.1	11.9*
Weight of water in uterus	3.9	0	3.9**	4.6	0	4.6**
Dockage on sows at market	14.5	4.5	10.0**	15.6	5.0	10.6**

* = Significant, ** = Highly significant.

feed necessary to produce 100 pounds of carcass were 586.3 pounds and 590.3 pounds, respectively, for the open and bred sows. This was calculated on the basis of feed consumed per 100 pounds of chilled carcass on the rail assuming that all sows would have dressed 75 percent when put on feed.

The slaughter and carcass data on the bred and open groups of sows are given in table 2. The open sows had a slightly higher dressing percentage than the bred sows. With dockage considered, however, the bred sows dressed highest, but the difference was not significant. In the thickness of fatback and yield of belly, both groups were very similar. In grade of belly and firmness of carcass, however, the bred sows were inferior. If the 1943

data had been included, the difference would have been still greater. The average weights of the bred sows when marketed during the three trials were 358, 408, and 377 pounds. During the tests, in which the sows were marketed at 358 and 377 pounds, the carcasses of the bred sows were distinctly softer than those of open sows of similar weights. The data on this point were not extensive enough to be final, but it was significant at the 5 percent level.

TABLE 4. SLAUGHTER AND CARCASS DATA ON ALL BRED VS. ALL OPEN SOWS. 1943, 1944 AND 1945 TRIALS

Items compared	Bred sows	Open sows
Number of sows (total)	22	35
Days pregnant	55.8	0
Number of pigs in uterus	8.8	0
Weight of uterus and contents	14.9	2.3
Weight of water in uterus	5.5	0
Dock on sows at market	18.0	4.4
Dressing %	76.5	79.4
Dressing % after docking	80.3	80.4

The differences between the bred and open groups of sows and between actually bred and actually open sows are given in table 3. In this paper an asterisk (*) or the word "significant" has been used to indicate that such a value could occur by chance in not more than five or less than one percent of similar trials. A double asterisk (**) or "highly significant" has been used to indicate a value that would occur by chance in one percent or less of similar trials. In general, the following conclusions appear justified from data in table 3: (1) Bred sows gain faster than open sows but have a heavier weight of uterus and contents. (2) Open sows excel bred sows in selling price or in reduced dockage, in dressing percentage, in firmness of carcass, and in grade of belly. (3) Bred and open sows are very much alike in daily gain when uterus and contents are eliminated, in shrink to market, in dressing percentage after docking, and in yield of belly.

Table 4 contains the data on the uterus and contents and the dressing percentage before and after docking on all sows during the three years' trials. As stated previously, all sows were used in this comparison as they were typical of those purchased regularly by packers even though those fed the first year may have been affected some by disease. As stated previously, the buyer had no information concerning which sows were bred and which sows were open. He passed a few that were bred, and docked a few that were open. Also, the dockage on the bred sows was slightly larger than the weight

of the uterus and contents. In the end, however, the dressing percentages of the two lots after docking were practically identical—80.3 and 80.4. This came about because the buyer had a tendency to dock the low-dressing, wasty, open sows. The open sows that were not docked dressed 79.8 percent while the open sows that were docked dressed only 78.2 percent.

Discussion

The bred sows in this study gained consistently faster and more economically than the open sows, thus corroborating the belief of many producers. During marketing, however, the above advantage was lost to the producer. This was true even when no breeding charge was made for the group of bred sows. The lower grade of bellies and lack of firmness in the bred sow carcasses indicate that the packer would have had to make a slightly larger differential between bred and open sows than he did if he were forced to sell the product on a discriminating market.

The small financial and efficiency differential between the bred and open sows when fattened for 60 days and slaughtered, indicates that a producer can market sows up to 60 days after breeding without any great losses to himself or the industry if they are carrying good finish. Thus, producers have some chance to change production plans during the early part of the gestation period if circumstances make selling desirable. Certainly, however, there is no advantage in breeding all sows in the feed lot if it is known they will be marketed as soon as fattened.

These findings are probably applicable only when the sows are fattened rapidly and have carried their litters 60 days or less as was done in this experiment. A survey was made of swine marketing in August of 1945 at the Morrell Packing Plant in Sioux Falls, South Dakota, to learn the scope and nature of the practice of breeding sows in the fattening lot for the territory served by this packing plant.[2] During that month, the kill consisted of 29.7 percent barrows and gilts, 35.3 percent open sows, and 35.0 percent bred sows. Thus it appears that approximately ½ of the producers in the area studied practice breeding sows in the fattening lot.

A representative sample from the month's kill was taken to estimate the length of time the sows had been bred before slaughtering. A total of 200 litters was studied in which weight and length of fetuses were taken on two head per litter. Warwick's (1928) tables were used to estimate the age of the fetuses. Table 5 gives percent of litters in the different age classes.

It appears from these figures that approximately ⅓ of the bred sows marketed in the Sioux Falls area are carrying litters from 0 to 60 days of age; a second ⅓ are carrying litters from 61 to 80 days of age; and the remainder have litters from 81 days up to age of parturition.

[2] These data, taken at Morrell Packing Plant, were collected by Edward Szczurek.

TABLE 5. PERCENT OF BRED SOWS WITH FETUSES IN DIFFERENT AGE CLASSES

Item compared	Age of fetuses in days						
	0–60	61–70	71–80	81–90	91–100	101–110	111+
Percent bred sows with fetuses in each age class	31.5	28.7	8.8	11.5	9.5	3.2	6.8

Any future research on this subject should probably be designed to include (1) different rates of fattening to allow an investigation of the effects of all stages of pregnancy, and (2) different degrees of finish at all stages of pregnancy. It seems likely that the effects of pregnancy on the carcass could be determined by studying packing house data in which the stage of pregnancy was estimated by Warwick's tables.

Summary

The comparative efficiency of bred and open sows when fattened and slaughtered was studied. The sows were full fed for an average feeding period of 57.5 days. Eighty-five percent of the individuals in the bred lot were carrying pigs when slaughtered. The average age of these litters was 55.8 days. The data showed that the lots of sows bred at the beginning of the trials (1) consumed 5.9 percent more feed daily, (2) gained 13.4 percent more weight daily and (3) required 6.4 percent less fed per pound of gain than open sows similarly fed and managed. The open sows, however, outsold the others by $0.34 per 100 pounds. Because of this differential, the bred sows returned 3.9 percent, $0.23 per head, less profit than the open sows.

A comparison of the carcass data of actually bred and actually open sows showed that the open sows excelled in (1) dressing percentage, 2.1 percent; (2) firmness of carcass, approximately ½ of a grade; and (3) grade of belly, approximately 1½ grades. The two groups of carcasses were similar in (1) thickness of fatback, and (2) yield of belly. Considering the dockage in both groups, the dressing percentages of the bred and open sows were 80.2 percent and 80.1 percent, respectively.

Breeding of sows during the fattening period appears, therefore, to be an undesirable production procedure for both producer and packer.

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METHODS OF MANAGEMENT OF A BROMEGRASS-ALFALFA MIXTURE[1]

R. F. Fuelleman, W. L. Burlison, and W. G. Kammlade[2]
Illinois Agricultural Experiment Station

THE productivity of pastures is influenced by many factors. Management is one of the principal factors affecting the yield of grass and legume pasture. Because of difficulties encountered in pasture research and because of the use of various methods in this work, investigations have sometimes yielded conflicting results. Accumulating data and more refinement in techniques are bringing the possibility of agreement nearer. Carrier and Oakley (1914) noted that close grazing over a short period of years gave better results than light grazing and that light grazing favored the incursion of weeds. Harrison *et al.* (1941) in making, comparisons between continuous and rotation grazing concluded that there was little difference in acre gains when rotation or continuous grazing was practiced. Data from the Illinois Agricultural Experiment Station at Dixon Springs (1946) over a period of six years indicate that heavy continuous and heavy alternate grazing gave larger animal gains per acre than moderate grazing. Under close grazing, weed infestations, particularly of broomsedge (*Andropogon virginicus*), were less evident.

Mechanical difficulties, particularly lack of fencing and the lack of alternate fields have been a barrier to practical farm utilization of the alternate system of grazing, although farmers, when permanent or rotation pastures become unproductive, usually have recourse to meadows, stubble fields, or corn stover.

This paper reports the results of experiments using alternate and continuous grazing with a mixture of smooth bromegrass (*Bromus inermis*, Leyss and alfalfa (*Medicago sativa*, L.) at Urbana, Illinois, during the period 1939 to 1945 inclusive.

Climatic Factors

Seasonal temperatures during the course of this study were normal for central Illinois with the exception of the fall of 1943 when a killing frost occurred on September 26. This was almost three weeks earlier than the average annual date for killing frost at this location.

Precipitation as indicated in table 1 fluctuated to some extent. Longtime average annual precipitation for central Illinois is approximately 36 inches.

[1] Contribution from the Illinois Agricultural Experiment Station, Urbana, Illinois. Published with the approval of the Director.

[2] Associate Professor, Crop Production; Head, Department of Agronomy; Professor of Sheep Husbandry, respectively.

During the years 1939–1945 a number of abnormal monthly precipitation periods occurred. Bromegrass and alfalfa are considered to be drought resistant species, however, bromegrass does not produce much top growth during dry periods. The total amount of precipitation is of less importance in forage growth than its distribution. During a given year when precipitation is well distributed throughout the grazing season, little difficulty is ordinarily experienced in pasturing from mid-April to mid-October. Since precipitation is usually not well distributed, reductions and additions of animals are necessary on continuously pastured fields.

TABLE 1. MONTHLY PRECIPITATION DURING GRAZING SEASON IN INCHES FOR YEARS 1939–1945 INCLUSIVE AT URBANA, ILLINOIS

Month	Inches of precipitation, by years						
	1939	1940	1941	1942	1943	1944	1945
April	5.39	3.96	4.21	3.32	3.47	7.43	4.37
May	1.19	4.53	3.94	3.57	11.20	7.70	5.09
June	6.17	5.04	6.19	3.92	2.43	2.61	7.33
July	1.73	0.95	3.27	4.94	1.42	3.82	3.27
August	6.38	2.80	3.61	2.58	3.94	3.85	5.09
September	0.32	0.48	4.91	3.89	2.12	2.82	7.27
October	2.54	1.93	9.01	2.36	2.00	1.29	2.45
Total for years	23.72	19.69	35.14	24.58	26.58	29.52	34.87

Plan of Experiment

A small field, located on the Agronomy South Farm of the Illinois Agricultural Experiment Station at Urbana, Illinois, was seeded in September 1939 with a mixture of 12 pounds of a Kansas strain of smooth bromegrass and eight pounds of Grimm alfalfa per acre. The field was fertile and had been used previously over a long period of years for various crops. An excellent stand was obtained.

The field was divided by cross fencing into five paddocks, four of which were two-fifths acre each, the fifth was one-fifth acre in size. The following conditions of utilization were imposed: Paddock (1) heavy continuous utilization, (2) moderate continuous, (3) alternate moderate, (4) alternate heavy utilization, and (5) a reserve paddock for the animals from the alternately pastured paddocks.

Yearling ewes and wether lambs purchased each spring were used as the grazing animals throughout this experiment. Since the fields were small, sheep were considered best because occasional losses from disease or accident could be replaced without seriously disrupting the experiment. Shelters, water, and salt plus Phenothiazine were provided.

The rate of stocking of each paddock was calculated to utilize available forage according to the experimental plan. Under continuous grazing fewer

animals per acre were needed than under alternate grazing. Some changes in numbers of animals were necessary depending upon rainfall and forage production as the seasons progressed. Animals were usually weighed at monthly intervals.

Forage yields were obtained on each weight day, using the cage method. All yields were calculated on a dry matter basis. Samples of forage from each paddock were taken on each sampling date for chemical analysis. Botanical analyses were made during each grazing season using either point quadrat for growing plants or hand separation methods of the harvested samples.

Experimental Results

Forage yields as shown in table 2 were uniformly high on all paddocks during the seasons of 1940 and 1941. This is generally true with respect to newly seeded pastures of a bromegrass and alfalfa mixture. During the following years with the reduction of alfalfa, forage yields declined despite the type of grazing management practiced.

TABLE 2. YIELDS OF DRY MATTER PER ACRE DURING GRAZING SEASONS OF 1940–1945 INCLUSIVE

Paddock	Type of utilization	Yields of dry matter in pounds per acre, by years						
		1940	1941	1942	1943	1944	1945	Av.
1	Heavy continuous	8,443	1,1458	6,781	4,128	4,542	3,873	6,537
2	Moderate continuous	9,087	1,1145	5,070	4,850	5,618	4,686	6,743
3	Moderate alternate	9,077	11,074	5,641	8,832	7,300	5,298	7,870
4	Heavy alternate	9,490	12,608	5,583	4,802	6,212	5,330	7,122

Yields of dry matter from each paddock declined approximately 4000 pounds between the years 1940 and 1945. The average annual yields for six years show that the two alternately grazed paddocks gave somewhat larger yields than the continuously grazed paddocks. Forage production during any given season on all paddocks was larger during May, June, and July than in following months. From 70 to 80 percent of the total seasonal yield was produced during the first three months. During seasons of heavy forage production and particularly in the months of May, June, and July much of the forage was not utilized by the animals. On the moderately grazed paddocks the bromegrass formed seed heads which were not consumed; also, large quantities of forage were trampled and wasted.

Botanical Analyses

Botanical analyses were made during each season except in 1939, when seedling stand counts were made on the field previous to fencing out the paddocks. This seedling count showed an average of 21 alfalfa seedlings and

33 bromegrass seedlings per square foot. An average of six weed seedlings, chiefly dandelion (*Taraxacum* species) also were found in each square foot. The botanical analyses were made using both the point quadrat, and the hand separation of composite samples from each paddock. These results are shown in table 3.

TABLE 3. BOTANICAL ANALYSES SHOWING PERCENTAGES OF SPECIES ON EACH PADDOCK

Year	Species	Paddocks and grazing methods			
		1 Heavy cont.	2 Light cont.	3 Light alt.	4 Heavy alt.
1940	Alfalfa	38.7	60.0	35.8	25.0
	Bromegrass	52.7	35.0	57.9	70.0
	Weeds and bare space	8.6	5.0	6.3	5.0
1941	Alfalfa	37.6	25.2	25.2	35.0
	Bromegrass	61.4	71.5	72.8	61.0
	Weeds and bare space	1.0	3.3	2.0	4.0
1942	Alfalfa	10.0	4.0	21.0	31.0
	Bromegrass	55.0	81.0	75.0	66.0
	Weeds and bare space	35.0	15.0	4.0	3.0
1943	Alfalfa	8.5	2.0	17.0	33.0
	Bromegrass	57.5	67.0	66.0	56.0
	Weeds and bare space	34.0	31.0	17.0	11.0
1944	Alfalfa	1.5	Trace	24.0	17.0
	Bromegrass	51.0	59.0	65.5	53.5
	Weeds and bare space	47.5	41.0	10.5	29.5
1945	Alfalfa	3.0	0.0	3.0	4.0
	Bromegrass	61.0	25.0	80.0	45.0
	Weeds and bare space	36.0	75.0	17.0	51.0

Under conditions of either heavy or moderate continuous grazing, alfalfa in the mixtures was reduced to a small percentage by the fall of 1942. (See table 3) Where alternate grazing was practiced, a similar reduction did not occur until 1945. Obviously, alternate grazing is the better system from the standpoint of maintenance of alfalfa in the stand. Continuous grazing gives alfalfa little opportunity for recovery. Although bromegrass is palatable, alfalfa is apparently more palatable. Under alternate grazing, rest periods aid in the recovery and maintenance of alfalfa over long periods of time.

Animal Gains and Pasture Days

No close relationship between animal gains and forage yields can be found in the data from the paddocks. (table 4) The important factors were the condition and kind of sheep. Animals purchased in 1940, 1941, 1942, and 1943 came from western and southwestern range areas. Their satisfactory initial weight and condition were good indicators of potential gains, although modifying factors such as parasites, temperatures, and dry periods frequently caused losses in weight. Periods of dry weather that reduced forage growth during a given season caused greater weight losses than any other factor. Exceptionally high weight gains were made in 1942. These gains resulted from a combination of good animals, succulent forage, and a uniform distribution of rainfall. Conversely, relatively low gains were made in 1944 when the amount of rainfall, although apparently adequate, was poorly distributed and there were several hot, dry periods.

Average, annual, animal-acre gains were highest under alternate-heavy utilization and lowest with continuous-moderate utilization (table 4). Similar results were obtained at the Dixon Springs Station in a comparable experiment with a pasture mixture of Kentucky bluegrass, Redtop, and Korean lespedeza.

During the six-year period of experimentation the average total number of days on pasture for each season was equal to four months on paddock 1 with heavy continuous grazing; five months on paddock 2 under moderate-continuous utilization; three months on paddock 3 with moderate-alternate grazing, and a similar period of time for paddock 4—heavy alternate grazing. In table 4, a column is shown representing the quantity of forage available for each pound of gain.In this respect there were few exceptions when there was not a wide variation between the amounts for the first two years of the experiment and the remaining four years. This is especially striking when the small quantity of dry matter available per pound of gain in 1942 is considered.

Protein and Mineral Content

Although samples for chemical analyses were obtained on each sampling date during the experiment all analyses were not completed. Data for the years 1940, 1941, and 1942 are shown in tables 5, 6, and 7.

The data on composition show a number of interesting trends. During the first two years i.e., 1940 and 1941, the protein percentages were at a high level on all paddocks. The high calcium content in 1940 is attributed to the larger amounts of alfalfa in the forages. In 1942 the protein percentages dropped sharply in July or late June indicating a small amount of alfalfa in the

TABLE 4. ANIMAL GAINS, SHEEP PASTURE DAYS, DAYS ON PASTURE AND FORAGE AVAILABLE PER POUND OF GAIN
1940–1945 INCLUSIVE

Year	Days on pasture	Sheep pasture days per paddock	Gain per acre of mutton, lbs.	Acre yields of dry matter, lbs.	Forage available per lb. of gain, lbs.
Paddock 1. Heavy-Continuous Grazing					
1940	131	384	120.0	8,443	70.3
1941	153	728	225.0	11,458	50.9
1942	148	888	417.5	6,781	16.2
1943	107	500	190.0	4,128	21.7
1944	122	578	245.0	4,542	18.6
1945	149	592	182.5	3,873	21.2
Total	810	3,670	1,380.0	39,225	
Average	135	612[1]	230.0	6,537	
Paddock 2. Moderate-Continuous Grazing					
1940	131	352	150.0	9,087	60.5
1941	153	364	130.0	11,145	85.7
1942	166	664	330.0	5,070	15.1
1943	154	616	170.0	4,850	28.5
1944	152	612	152.5	5,618	36.7
1945	149	592	237.5	4,686	19.7
Total	905	3,200	1,170.0	40,456	
Average	151	533[2]	195.0	6,743	
Paddock 3. Moderate-Alternate Grazing					
1940	78	215	150.0	9,077	60.5
1941	96	380	215.0	11,074	51.5
1942	106	636	467.0	5,641	12.1
1943	98	524	233.0	8,832	37.9
1944	74	336	95.0	7,300	76.8
1945	83	440	225.0	5,298	23.6
Total	535	2,531	1,385.0	47,222	
Average	89	422[3]	230.8	7,870	
Paddock 4. Heavy-alternate grazing					
1940	78	156	165.0	9,490	57.5
1941	96	380	225.0	12,608	56.0
1942	106	424	590.0	5,583	9.5
1943	84	316	245.0	4,802	19.6
1944	94	380	105.0	6,212	59.1
1945	94	332	175.0	5,330	30.5
Total	552	1,988	1,505.0	44,025	
Average	92	331[4]	250.8	7,337	

[1] Sheep pasture days per acre equals 1530.
[2] Sheep pasture days per acre equals 1332.5.
[3] Sheep pasture days per acre equals 1055.
[4] Sheep pasture days per acre equals 1655.

TABLE 5. CHEMICAL COMPOSITION OF FORAGES FOR 1940

Sampling dates	Protein, percent	Calcium, percent	Phosphorus, percent	Magnesium, percent
Paddock 1				
May 20	20.17	2.11	.352	.361
June 1	18.00	2.90	.263	.381
August 13	19.25	1.88	.284	.381
September 19	23.63	1.22	.311	.343
October 10	20.25	1.54	.249	.304
Paddock 2				
May 20	20.17	2.11	.352	.361
June 1	14.25	1.23	.300	.404
August 13	18.13	1.53	.259	.282
September 19	22.50	1.43	.299	.351
October 10	16.88	.844	.256	.387
Paddock 3				
June 1	15.00	2.16	.235	.442
August 13	19.94	1.74	.259	.282
September 19	22.50	1.43	.299	.351
October 10	18.63	1.08	.252	.352
Paddock 4				
June 1	14.50	1.50	.303	.425
August 13	19.88	1.71	.229	.301
September 19	20.10	1.26	.323	.263
October 10	22.63	1.26	.225	.283

samples. Also at this time bromegrass usually matures seed and the quantity of leafy herbage is small, thereby decreasing the protein. The percentages of calcium also decrease with a decrease in the alfalfa content of the forage. In some instances this is also caused by mechanical difficulties encountered in harvesting uniform samples from grazed areas. Forage samples from paddock 4 in 1942 were relatively higher in protein, calcium, and phosphorus than those from the other paddocks. This was the result of more uniform grazing coupled with the rest periods in the alternate systems of grazing.

Discussion of Grazing Procedure

In the original plan of this experiment grazing animals were to be moved on specific dates. On continuously pastured plots the numbers of sheep were predetermined each season according to the amount of forage available.

TABLE 6. CHEMICAL COMPOSITION OF FORAGES FOR 1941

Sampling dates	Protein, percent	Calcium, percent	Phosphorus, percent	Magnesium, percent
		Paddock 1		
May 3	22.25	.743	.452	.196
June 4	17.25	.590	.379	.150
July 8	20.31	.899	.433	.280
September 3	20.69	.891	.397	.235
October 2	24.31	.833	.568	.277
November 4	21.50	.727	.411	.224
		Paddock 2		
May 3	25.19	1.02	.437	.128
June 4	20.06	.931	.406	.242
July 8	27.63	.743	.452	.235
September 3	20.50	.898	.376	.208
October 2	23.69	1.071	.552	.262
November 4	21.25	.621	.417	.212
		Paddock 3		
May 3	24.06	.991	.393	.201
June 4	20.19	.812	.373	.236
July 8	20.75	.969	.450	.262
September 3	20.19	1.109	.389	.247
October 2	21.19	1.206	.413	.233
November 4	16.69	.682	.332	.175
		Paddock 4		
May 3	26.00	1.200	.427	.206
June 4	20.00	1.012	.396	.209
July 8	26.63	1.024	.392	.239
September 3	21.88	1.302	.377	.283
October 2	21.19	1.383	.438	.302
November 4	19.81	.830	.388	.219

Neither of these plans could be followed exactly. Some changes were necessary particularly on the heavy-continuously grazed paddock. As the experiment progressed, it became increasingly apparent that the number of animals per acre on the heavy-alternately grazed pasture should be decreased or the grazing period shortened. The rate of stocking on the heavy-continuously grazed pasture was 16 per acre; on the moderately-grazed paddocks 10 per acre, and on the heavy-alternately grazed paddock 20 per acre. Alternately pastured fields were grazed in May, July, August, and October. Dry periods

TABLE 7. CHEMICAL COMPOSITION OF FORAGES FOR 1942*

Sampling dates	Protein, percent	Calcium, percent	Phosphorus, percent
Paddock 1			
May 2	21.60	.741	.316
May 29	14.44	.650	.343
June 29	19.87	.650	.315
July 27	14.69	.476	.312
August 31	18.72	.535	.318
September 25	20.00	.734	.298
Paddock 2			
May 2	21.81	.589	.324
May 29	16.31	.588	.302
June 29	11.56	.510	.295
July 27	14.19	.511	.306
August 31	13.56	.475	.269
September 25	10.88	.533	.260
October 17	11.37	.494	.198
Paddock 3			
May 2	19.69	.640	.290
May 29	13.63	.682	.293
June 30	12.63	.517	.245
July 29	10.00	.420	.217
August 31	14.14	.576	.250
September 25	18.88	.642	.350
October 17	14.12	.577	.272
Paddock 4			
May 2	21.81	.767	.402
May 29	14.06	.870	.308
June 30	16.69	.696	.377
July 27	11.94	.615	.314
August 31	19.56	.742	.330
September 25	22.12	.866	.396
October 17	17.06	.609	.280

* No magnesium analyses were made in 1942.

frequently made it necessary to change this schedule particularly in 1943 and 1944.

Summary and Conclusions

Four degrees of grazing were used on bromegrass-alfalfa mixture pastures. These were heavy-continuous, moderate-continuous, moderate-alternate, and heavy-alternate utilization.

Soil on these paddocks was fertile and forage yields were high despite the method of pasture management. Although a system of heavy-continuous grazing is usually not advocated, during a short period of years the results obtained in this experiment indicated that livestock utilize the forage to better advantage than under moderate grazing management. Under the latter system, large quantities of forage are trampled by animals, and this causes smothering with subsequent spottiness of the grass cover. The heavier grazing may be best for pasture grown in a crop rotation.

Heavy-alternate systems of grazing, where rest periods for the pasture were used, provided the best utilization of the forage when it was most palatable and nutritious. This system gave bromegrass and alfalfa an opportunity to produce new growth during the growing season, something which was not possible under continuous grazing conditions.

Alfalfa was eliminated most rapidly from the continuously grazed paddocks because it had no chance to recover as in the alternately grazed paddocks. Under moderate grazing conditions (both continuous and alternate) alfalfa suffered from the aggressive competition of bromegrass. The tendency of bromegrass to become stemmy and coarse reduced its palatability; under these conditions the animals selectively grazed the alfalfa.

Forage yields were very large for all paddocks during 1940 and 1941, but a regular downward trend occurred on all paddocks during the remainder of the six-year period. Yields of forage on fertile soil, under reasonable grazing management, usually recede to a level that can be maintained almost indefinitely. This level is in the neighborhood of 4000 pounds of dry matter per acre. Previous work at this station showed that a bromegrass-Kentucky bluegrass mixture over an eight-year period, including the drought years of 1934 and 1936, averaged more than 4000 pounds of dry matter per acre.

When chemical analyses showed high protein and calcium percentages this was indicative of a high legume content in the forages. Alfalfa contains a high percentage of protein which is maintained at a relatively high level throughout the grazing season. Alfalfa also contains a high percentage of calcium; with a reduction of alfalfa in the stand, these percentages dropped sharply. Chemical analyses also showed a seasonal trend, particularly where little or no alfalfa was present. The high protein percentages occur in May, June, and October; during July, August and September these percentages are relatively low. This leads to the obvious conclusion that any system of grazing which permits maintenance of legumes over the longest period of time, gives the greatest returns in forage yields and nutrients. Animal gains were highest under heavy-alternate utilization of pasturage and percentages of alfalfa on these paddocks remained relatively high during the first five years of the experiment.

Under farm conditions it would be possible to divide a pasture by fencing and to graze it alternately to obtain results comparable to those obtained in this experiment.

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THE APPARENT DIGESTIBILITY OF PRAIRIE HAY OF VARIABLE PROTEIN CONTENT, WITH SOME OBSERVATIONS OF FECAL NITROGEN EXCRETION BY STEERS IN RELATION TO THEIR DRY MATTER INTAKE

WILLIS D. GALLUP AND H. M. BRIGGS[1]
Oklahoma Agricultural Experiment Station

A COMPLETE knowledge of the factors that contribute to the nutritive value of native grass and hay is of both practical and scientific value. Seasonal and environmental factors contribute largely to variations in the nutrient content of the grass, and other less well-defined factors apparently influence the availability of these nutrients in digestion. Factors associated with the physical characteristics and palatability of grass need to be investigated in relation to stage of maturty of the grass, its chemical composition, and nutrient digestibility. Finally, for practical purposes, it would be desirable to have an accurate estimate of the feeding value of native grass expressed in terms of the feed requirements of animals utilizing the grass.

Recently, attempts were made to determine by indirect methods the seasonal variation in the apparent digestibility of native grass as grazed by steers on pasture (Hobbs, Gallup and Taylor, 1945). Continuation of this work has been delayed by difficulties encountered in securing reliable estimates of the feed intake of animals while grazing. Seasonal variation in the digestible nutrients of native grass cured for hay (prairie hay) is now being investigated (Briggs *et al.*, 1946). In the progress of this and other work involving nitrogen balance experiments with steers, advantage has been taken of the opportunity to determine the digestibility of unsupplemented and supplemented native hay rations of varying composition. The digestive wastage of protein is considerable when cattle are fed fibrous rations, therefore particular attention was given to this loss in the digestion trials discussed in the present paper.

Materials and Methods

Complete botanical descriptions and the official grades of the various lots of prairie hay used in these experiments were not available. The hay was produced in the local area. It was composed largely of Little and Big Bluestem, with smaller amounts of less common grasses and some weeds. The different lots of hay varied in quality as would be expected of hay cut under favorable and unfavorable conditions in different seasons and in different years. The cottonseed meal which was fed as a supplement to the hay in

[1] Departments of Agricultural Chemistry Research and Animal Husbandry, respectively, Stillwater, Oklahoma.

some trials was of average quality. Its protein content varied from 43.3 to 46.3 percent (dry-matter basis).

The steers were yearling and two-year old Herefords that weighed from 545 lbs. to 763 lbs. During the digestion trials they were fed prairie hay according to appetite and 0.0, 0.5, 1.0, 1.5, 2.0, 2.3, and 3.0 lbs. of cottonseed meal daily. Block salt was available at all times. The digestibility of each ration was determined with four or more steers. The order of feeding the rations was so arranged that only seldom was the same ration fed to different steers during the same period. The procedures followed in these trials and the methods employed in collection and analysis of feeds and excreta were essentially the same as those previously described (Briggs, Gallup and Darlow, 1946).

Results and Discussion

Table 1 shows the variations in the chemical composition of the different lots of prairie hay consumed by the steers during the digestion trials when hay alone was fed. These values, and similar ones for the supplemented hay rations, are arranged in table 1 in order of increasing protein content. For convenience of comparison, the same arrangement has been maintained in presenting the digestibility values for the rations in table 2. Differences among the ten lots of hay were confined largely to differences in protein content, which varied from 3.01 percent to 5.85 percent. There was no apparent relationship between the content of protein and other major nutrients of the hay. Crude fiber values were characteristically high, even for the hay of relatively high protein content.

The protein content of the supplemented rations increased roughly in proportion to the amount of cottonseed meal added, irregularities being caused by variations in composition of both hay and meal. Nitrogen-free extract was decreased slightly while ether extract was increased in the supplemented rations of high-protein content. The apparent digestibility of nutrients in the hays and supplemented rations, with other data, are presented in table 2.

Digestibility of Rations

Several important relationships are brought out in table 2. In particular it should be noted that the digestibility of nutrients of the hay increased in a fairly uniform manner as the protein content of the hay increased from 3 percent to about 6 percent. The digestibility of dry matter increased from approximately 46 percent to 60 percent; the apparent digestibility of protein, as might be expected, increased markedly from negative values to 41.2 percent; while crude fiber digestibility increased from about 56 percent to 69 percent. These values which, with few exceptions, are positively corre-

lated with protein content, show no relationship to the content of crude fiber or other nutrients of the hay.

When the protein content of the hay is correlated with the apparent protein digestion coefficient of the hay, the correlation coefficient is 0.924. The regression is described by the equation:

$$y = -51.7 + 16.2\,x$$

in which y is the apparent digestibility of the protein and x is the protein content of the hay when both values are expressed as percentages. Also, the

TABLE 1. COMPOSITION OF PRAIRIE HAY, SUPPLEMENTED RATIONS, AND COTTONSEED MEAL CONSUMED BY STEERS IN DIGESTION TRIALS

Description	Digestion trial number	Hay lot number	Dry matter	Composition of dry matter				
				Ash	Protein	Ether extract	Crude fiber	N-free extract
			per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Prairie hay	1	1	90.22	7.88	3.01	2.36	31.52	55.23
do.	2	2	92.53	8.60	3.20	2.44	33.60	52.16
do.	3	3	90.35	8.78	3.81	2.03	32.12	53.26
do.	4	4	92.50	6.34	3.93	2.30	34.96	52.47
do.	5	5	92.51	6.63	4.00	2.51	34.32	52.54
do.	6	6	92.69	6.90	4.18	2.75	34.55	51.62
do.	7	7	92.82	5.93	4.67	2.44	35.79	51.20
do.	8	8	92.84	6.45	4.71	2.29	34.07	52.48
do.	9	9	93.44	6.14	5.50	1.72	35.10	51.54
do.	10	10	92.71	6.00	5.85	2.28	34.96	50.92
Supplemented ration[1]	11	7	92.73	6.49	5.48	2.58	31.60	53.85
do.	12	6	93.40	7.21	6.22	2.77	32.14	51.55
do.	13	3	90.61	9.33	7.65	2.44	29.85	50.73
do.	14	1	90.47	7.59	8.67	3.10	28.56	52.08
do.	15	2	92.19	8.15	10.83	3.09	28.80	49.13
do.	16	6	93.15	6.39	10.85	2.95	30.37	49.44
do.	17	4	91.45	6.32	11.33	3.07	31.00	48.28
do.	18	10	91.49	6.28	12.00	3.05	31.16	47.51
do.	19	6	92.71	6.53	13.42	3.97	27.94	48.13
Cottonseed meal	11		91.17	6.02	46.29	7.15	9.83	30.71
do.	12, 16		91.21	5.89	45.24	6.91	10.01	31.95
do.	13		92.37	8.34	44.79	6.06	10.36	30.45
do.	14		91.47	6.08	45.04	7.76	10.15	30.97
do.	15		91.63	6.38	43.80	6.68	10.17	32.97
do.	17, 18		92.23	5.72	44.56	6.22	10.17	33.33
do.	19		92.08	5.90	43.30	8.93	9.77	32.10

[1] The supplemented rations were composed of prairie hay and cottonseed meal in the amounts shown in table 2.

T.D.N. value of the hay is highly correlated with its protein content as shown by a correlation coefficient of 0.830. The regression is described by the equation:

$$y = 28.0 + 4.9\,x$$

in which y is the T.D.N. content of the hay and x is the protein content of the hay when both values are expressed as percentages.[2]

Likewise, in the supplemented rations the digestibility of all nutrients was greatest in the rations of highest protein content. However, as the protein content of the rations increased from 5.5 percent to 13.4 percent, only

TABLE 2. APPARENT DIGESTIBILITY OF PRAIRIE HAY AND OF RATIONS OF PRAIRIE HAY AND COTTONSEED MEAL OF VARIABLE PROTEIN CONTENT, BY STEERS; AND FECAL NITROGEN EXCRETION IN RELATION TO DRY MATTER INTAKE

Trial[1]	Average weight	Average daily dry matter intake			Apparent digestibility of—					T.D.N. (air-dry basis)	$\frac{\text{Fecal N}}{\text{Dry matter intake}} \times 100$
		Prairie hay	Cotton seed meal	Protein	Dry matter	Protein	Ether extract	Crude fiber	N-free extract		
	grams	*grams*		*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	
1	545	3684		3.01	46.9	−9.9	15.2	55.6	50.4	41.4	0.54
2	570	3216		3.20	48.0	−0.8	36.4	59.8	48.9	45.3	0.52
3	623	3576		3.81	45.8	7.1	7.4	56.2	47.6	39.8	0.58
4	581	2907		3.93	50.6	13.3	39.8	61.6	51.8	47.4	0.54
5	577	3100		4.00	54.1	23.9	45.1	64.3	54.9	50.3	0.48
6	759	4204		4.18	53.7	13.3	37.4	63.9	56.4	50.1	0.58
7	629	3945		4.64	56.5	29.5	48.5	65.1	58.3	53.1	0.52
8	579	3359		4.71	57.8	30.1	41.4	65.3	60.2	53.3	0.53
9	612	4038		5.50	55.0	30.9	27.5	66.9	57.3	52.1	0.61
10	589	3542		5.85	60.5	41.2	47.7	68.9	62.1	56.2	0.55
11 (7)	631	4190	206	5.48	54.7	33.3	37.0	61.8	59.6	51.5	0.59
12 (6)	763	4242	206	6.22	53.8	35.0	38.7	60.8	58.2	50.6	0.65
13 (3)	616	4076	419	7.65	53.5	44.9	27.0	61.4	55.8	46.7	0.67
14 (1)	587	3943	622	8.67	53.4	48.2	48.0	65.2	54.0	49.1	0.72
15 (2)	607	4131	962	10.83	54.3	58.0	57.3	62.6	55.9	51.4	0.73
16 (6)	698	4243	828	10.85	58.2	58.0	60.8	64.2	60.3	55.6	0.73
17 (4)	624	4108	837	11.33	56.5	59.7	60.3	63.6	55.4	52.4	0.73
18 (10)	620	4081	837	12.00	64.4	62.9	63.8	69.3	65.9	58.4	0.71
19 (6)	752	4214	1252	13.42	59.6	60.1	73.2	66.5	59.9	57.5	0.86

[1] The figures in parenthesis refer to the lot number of the hay used in the supplemented rations. There were small variations in the composition of the same lot of hay used in different trials.

the digestibility of protein and, with one exception (trial 13), that of ether extract increased in a somewhat regular manner. Changes in the digestibility of other individual nutrients were small and irregular and appeared to be

[2] Professor Carl E. Marshall of the Mathematics Department assisted in the statistical analysis of these data.

related more closely to variations in quality and composition of the different hays than to differences in protein content of the entire ration. For example, when hay no. 4 and hay no. 10 were supplemented with equal amounts of cottonseed meal and fed in trials 17 and 18, respectively, markedly higher digestibility values were obtained for all nutrients in the ration containing the high protein hay, no. 10. The comparatively low digestibility values obtained in trial 15, when poor quality hay (lot no. 2) was supplemented with as much as 2.3 pounds of cottonseed meal daily, may be explained on the same basis. These comparisons indicate that the protein content of native hay appears to be a reliable index of the nutritive value of hay rations containing similar supplements.

Differences between the unsupplemented and the supplemented rations unrelated to hay quality and ascribed to the addition of protein supplement are shown in a comparison of the results obtained in trials 1 and 14, 2 and 15, and other corresponding pairs of trials when hay of the same lot was fed. In 8 of the 9 permissible comparisons, differences in digestibility of all nutrients favored the supplemented rations. Further, the addition of protein supplement, even in such small amounts as 0.5 pound daily, produced a marked increase in hay consumption. The effectiveness of small amounts of cottonseed meal in bringing about this increase is of considerable practical significance.

Fecal Nitrogen Excretion

Values for the amount of fecal nitrogen excreted per 100 grams of dry matter consumed are presented in the last column of table 2. The total amount of nitrogen of the feces, which includes undigested feed nitrogen plus that resulting from activity of the gastro-intestinal tract, constitutes the wastage of protein ($N \times 6.25$) in digestion in its broadest sense. The division of fecal nitrogen into these two fractions, residual feed nitrogen and so-called "metabolic" nitrogen, has been discussed at length by Mitchell (1926) in showing that the latter fraction is directly proportional to the amount of dry matter eaten. Since metabolic nitrogen constitutes such a large proportion of the total nitrogen of the feces, especially when the rations fed are relatively low in protein and high in fiber, it follows that under similar conditions total fecal nitrogen should likewise be closely related to dry matter intake.

In the present experiments total fecal nitrogen per 100 grams of dry matter intake varied only slightly from 0.55 gram when the various lots of hay of increasing protein content were fed without supplements. Higher values which tended to vary directly with the protein content of the ration were obtained when the supplemented rations were fed. For rations containing

from 6.22 percent to 12 percent protein, however, total fecal nitrogen excretion was about 0.71 gram per 100 grams of dry matter intake.

It appears, therefore, that the total fecal nitrogen excretion of steers is so related to their dry matter intake that when either of these quantities is known the other one can be closely approximated by the use of an appropriate factor. This factor, which is 0.55 for prairie hay containing from 3 percent to 6 percent of protein (dry basis), will vary for different feeds and different combinations of the same feeds; but for any given roughage it should remain fairly constant over a relatively wide range of variations in composition. For example, fecal nitrogen per 100 grams of dry matter intake calculated from average figures in Morrison's (1936) tables was found to be 0.71 ± 0.03 gram for five grades of alfalfa hay listed as all analyses, very leafy, leafy, fair and stemmy. The alfalfa varied from 12.1 percent to 16.5 percent in protein. Likewise average figures from the same source summarized by Mitchell (1942) show that for roughages as a class containing from 8 percent to 16 percent protein and from 16 percent to 24 percent protein, fecal nitrogen excretion on the same basis is 0.67 gram and 0.76 gram, respectively. These general relationships between fecal nitrogen excretion and dry matter intake apparent in the results of digestibility studies with roughages may provide a basis for estimating the forage consumption of grazing animals when feces are collected in the manner described by Rusk and Garrigus (1939). First, however, it needs to be shown that these relationships will not be altered by grazing conditions or by normal change in composition of the particular forage under investigation (Hobbs, Gallup and Taylor, 1945).

Summary

In an investigation of the apparent relationship between the proximate composition of prairie hay and its nutritive value, digestion trials were carried out with steers receiving prairie hay, alone, and supplemented with varying amounts of cottonseed meal. Total digestible nutrients of the hay increased in a fairly uniform manner from 41 percent to 56 percent as the protein content of the hay increased from about 3 percent to 6 percent. Likewise, crude fiber digestibility increased from 56 percent to 69 percent while the apparent digestibility of protein increased from negative values to 41 percent.

When cottonseed meal in amounts varying from 0.5 lb. to 3 lbs. daily was fed as a supplement to 10 lbs. of hay, differences in digestibility related to the protein content of the hay were again apparent. The digestibility of dry matter in the high-protein hay was equal to that in rations made up of average or low-protein hay supplemented with 2 lbs. of cottonseed meal.

A close relationship between protein content and digestibility of nutrients in hay is indicated in these results.

Wastage of protein in digestion, expressed as nitrogen lost in the feces per 100 grams of dry matter intake, varied only slightly from 0.55 gram when hay alone was fed and increased to about 0.71 gram when cottonseed meal was fed as a supplement. It is suggested that when conditions permit the feed consumption of grazing animals can be determined by taking advantage of the relationship between fecal nitrogen excretion and dry matter intake.

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CULL PEAS AS A PROTEIN SUPPLEMENT FOR SWINE FEEDING[1]

T. J. Cunha, E. J. Warwick, M. E. Ensminger and N. K. Hart
State College of Washington[2]

THE Palouse area of eastern Washington and northern Idaho is the leading dry pea producing area in the United States. The crop is grown primarily for human food, but the cull peas which consist of weevil damaged, shriveled, cracked, and small peas are unfit for human consumption, an after separation from the sound peas, are available as a livestock feed. Since approximately 3.5 to 4.0 percent of the crop consists of cull peas, a large tonnage is available each year, and it is of importance that their feeding value be established.

Woods, Beeson, and Bolin (1943) reported that the Alaska field pea is an excellent source of the amino acids essential for rat growth, with the single exception of methionine. Cunha and Lindley (1945) found that the addition of 0.3 percent methionine to a ration (containing 16% total protein) of wheat, barley, cull peas, 5% alfalfa, and minerals was of no help in rat growth. This indicates that, even though the peas themselves are low in methionine, the addition of barley, wheat, and alfalfa in the ration provided enough additional methionine to supply the rat's needs for growth. This is in line with data reported by Evans (1945) which show that the proteins of wheat, barley, and alfalfa are higher in methionine than the proteins of Alaska peas.

Work reported by Warwick and Cunha (1944, 1945, 1946) with growing-fattening pigs on pasture showed that rations with cull peas as the protein supplement produced essentially the same gains and as a high a degree of finish as rations containing mixtures of meat meal, soybean oil meal, and linseed meal or rations containing meat meal or soybean oil meal as the only protein supplement. Warwick and Cunha (1945 and 1946) in trials with pigs on sudan grass pasture showed that pigs can successfully be fed 70, 85 or 98.5 percent of cull peas throughout the growing-fattening period. In these latter trials, cull peas were being used both as a protein supplement and a grain substitute.

Lehrer, Beeson and Wilson (1946) reported that no animal protein supplement is needed when cull peas are fed as the only protein supplement for

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hogs on good pasture. Beeson and Hickman (1945 and 1946) and Lehrer and Hodgson (1946) reported that rations containing ground cull peas as the protein supplement for growing-fattening pigs in dry lot did not give as good results as when some meat meal was included in the ration.

The experiments reported herein were conducted to determine how adequate cull peas are as a protein supplement for growth, reproduction and lactation of swine fed in dry-lot.

Experimental

In 1945, 6 lots of 10 Chester White pigs each were fed. In 1946, 5 lots of 11 Chester White pigs were used. The pigs were selected and distributed equally in each lot with respect to initial weight, age, and sex. The pigs were fed in dry-lot on concrete floors.

In 1945 a comparison was made between soybean oil meal, tankage, and cull peas as protein supplements. This comparison was made with two levels of alfalfa in the ration, 5 and 15 percent respectively. In 1946 a comparison was made between cull peas and tankage as a protein supplement with both rations containing 5 percent alfalfa meal. In one lot, wheat as the sole grain was compared with a combination of wheat and barley. A comparison was also made with two levels of alfalfa in the ration, 5 and 15 percent, with cull peas as the protein supplement.

In 1945, the pigs were started on experiment when they averaged 50 lbs. live weight, and in 1946 they averaged 65 lbs. In 1945 the pigs were fed for 125 days, and for 126 days in 1946. At the close of the growth trials, representative gilts were selected from the various lots, bred, and followed through gestation and lactation.

The amount of protein fed in each lot during growth was equalized so that, regardless of which protein supplement was fed, the pigs were obtaining the same amount of total protein in the ration. Since the requirement of the pig for protein decreases as it becomes heavier in weight, the protein content of the ration was lowered as the pigs increased in size. The total protein contents of the rations used were as follows:

Pigs weighing 50–75 lbs.—20 percent total protein in the ration
Pigs weighing 75–125 lbs.—16 percent total protein in the ration
Pigs weighing over 125 lbs.—14 percent total protein in the ration

The rations fed were as follows:

1945

Lot 1—Wheat[2], barley[2], meat meal, 5% alfalfa, and minerals[4]
Lot 2—Wheat, barley, meat meal, 15% alfalfa, and minerals

[2] Wheat and barley were included in equal amounts in all the rations when both were fed.

[4] With the rations containing tankage, 0.5 percent of iodized salt was added. With all the other rations 0.5 percent iodized salt, 0.5 percent steamed bone meal, and 0.5 percent of ground oyster shell were included in the ration.

Lot 3—Wheat, barley, cull peas, 5% alfalfa, and minerals
Lot 4—Wheat, barley, cull peas, 15% alfalfa, and minerals
Lot 5—Wheat, barley, soybean oil meal, 5% alfalfa, and minerals
Lot 6—Wheat, barley, soybean oil meal, 5% alfalfa, and minerals

1946

Lot 7—Wheat[2], barley[3], meat meal, 5% alfalfa, and minerals[4]
Lot 8—Wheat, barley, cull peas, 5% alfalfa, and minerals
Lot 9—All wheat, cull peas, 5% alfalfa, and minerals
Lot 10—Wheat, barley, cull peas, 15% alfalfa, and minerals
Lot 11—Wheat, barley, cull peas, 15% alfalfa, and minerals

The feeds used may be described as follows: *Wheat and barley*—good quality feed grains grown locally; *Meat meal*—dry-rendered, 55 percent protein grade; *Soybean oil meal*—Expeller process; *Cull peas*—grown in eastern Washington, largely of the Alaska variety, separated by gravity: *Alfalfa meal*—ground leaf and stem meal, dehydrated.

Results and Discussion

Table 1 summarizes the results obtained during the growing-fattening period. With 5 percent of alfalfa meal in the ration (lots 1, 3 and 5), the pigs fed cull peas as a protein supplement gained as fast as the pigs fed meat meal and a little faster than those fed soybean oil meal as a protein supplement. The pounds of feed required per 100 pounds of gain were lower for the pigs fed cull peas. Since the cull peas were the cheapest protein supplement fed and since the pigs fed the cull peas required the least amount of feed, the cheapest gains were made by the pigs fed this protein supplement.

With 15 percent alfalfa meal in the ration (lots 2, 4 and 6), the pigs fed cull peas as a protein supplement gained faster than the pigs fed either meat meal or soybean oil meal as a protein supplement. Again the cost of the gains was much cheaper for the pigs fed cull peas than for those fed meat meal or soybean oil meal. Analysis of variance of the average daily gains indicated that there were highly significant differences between the protein supplements and between the levels of alfalfa fed.

In the 1946 trials, the pigs fed meat meal as a protein supplement with 5 percent alfalfa in the ration had a lower average daily gain than the pigs fed cull peas with 5 percent alfalfa in the ration (lots 7 and 8), and the average daily gains were significantly more variable in the lot of pigs fed meat meal. In addition, at the prevailing feed prices, it cost $3.50 more per 100 lbs. of gain for the pigs fed meat meal as compared to the pigs fed cull peas as a protein supplement. In each of the two years' trials, a mange-like condition affected several of the pigs fed meat meal. This condition did not respond to repeated treatments with oil or coal tar dips. In the 1946 trials, five of the pigs fed meat meal in lot 7 developed the mange-like skin condition

TABLE 1. GROWTH DATA WITH PIGS FED IN DRY LOT

Items compared	1945						1946				
Lot No.	1	3	5	2	4	6	7	8	9	10	11
Protein supplement	Tankage	Cull peas	Soybean oil meal	Tankage	Cull peas	Soybean oil meal	Tankage	Cull peas	Cull peas	Cull peas	Cull peas
Amount of alfalfa fed	5	5	5	15	15	15	5	5	5	15	15
Kind of grain fed	W & B*	W & B	W & B	W & B	W & B	W & B	W & B	W & B	W	W & B	W & B
Ave. daily gain, lbs.	1.20	1.22	1.10	1.05	1.14	0.99	1.00	1.22	1.12	1.05	1.04
Ave. daily feed consumption, lbs.	5.77	4.98	4.95	5.48	5.45	5.15	5.61	5.92	5.27	5.56	5.56
Feed per 100 lbs. gain, lbs.	482.3	408.4	450.8	521.7	476.2	518.5	561	486	471	529	534
Cost of feed per 100 lbs. gain**	$11.25	$8.27	$10.41	$11.60	$9 27	$11.38	$14.53	$11.03	$11.16	$11.48	$11.59

* W = wheat, B = barley.

** Cost of feeds per ton (first cost is for 1945 and second cost for 1946); wheat 44.00 and 52.50; barley 42.00 and 45.00; Soybean oil meal 63.00; Tankage 75.00 and 78.75; Cull peas 39.00 and 43.00; alfalfa 26.50 and 26.50; Iodized salt 28.00 and 38.50; Steamed bone meal 60.00 and 55.00; and ground oyster shell 24.00 and 28.00.

(figure 1). A veterinary pathologist[5] examined the pigs, taking scrapings, but found no evidence of mange mites. When the experiment was finished, these five pigs were turned out to pasture and their mange-like skin condition gradually disappeared. It is possible that a lack of some nutrient or nutrients in meat meal caused the abnormal skin condition. If tankage lacked some factor(s), they evidently were present in cull peas since no pigs in any of the four lots (lot 8 to 11) fed peas developed the abnormal skin condition. A possible explanation for cull peas showing up so well as a protein supplement as compared to meat meal is that the meat meal being produced now is not as good in quality as the pre-war product.

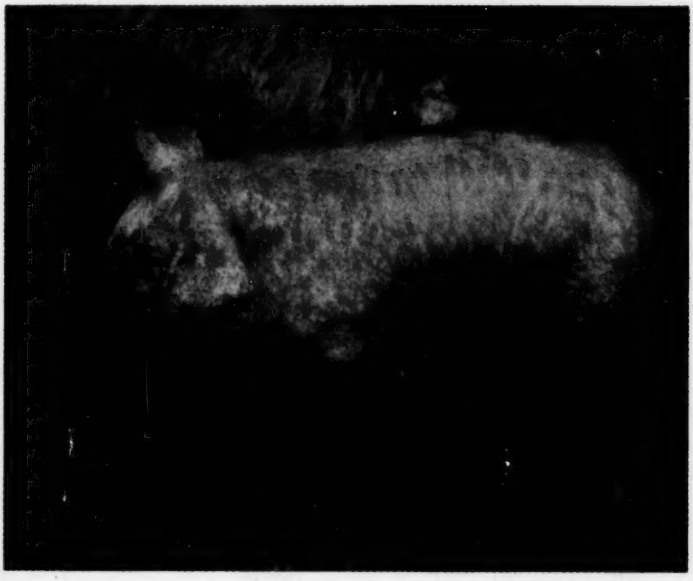

Figure 1. Note the abnormal skin condition. This skin condition was observed only with the pigs fed tankage. This skin condition cleared up when the pigs were turned out to pasture.

The data in table 1 show that the gains made by the pigs were lowered when 15 percent alfalfa instead of 5 percent alfalfa was included in the ration. These lower gains were probably due to the increased fiber content of the ration. However, there is a very important advantage to using higher levels of alfalfa during the growth period as will be shown (tables 2 and 3) when the pigs are later kept for reproduction and lactation.

[5] Dr. D. R. Cordy, College of Veterinary Medicine, State College of Washington.

Reproduction and lactation

The data shown in table 2 indicate that in no case, with any of the rations studied, were there very good results obtained during reproduction and lactation. The data show that cases of sterile gilts were obtained in all lots where the gilts had been fed 5 percent of alfalfa during their growing-fattening period. No cases of sterility were obtained in the lots where the gilts had been fed 15 percent of alfalfa during their growing-fattening period. These data indicate that the ration fed during growth is very important and that it influences results obtained later during reproduction and lactation. These data substantiate those obtained by Cunha *et al.* (1944) with gilts fed corn-soybean oil meal rations instead of wheat, barley and pea rations.

The 1945 data (table 2) show that poor results were obtained during repro

TABLE 2. REPRODUCTION AND LACTATION DATA

Lot No. from which gilts were taken	Ration gilts were fed during growth (in dry-lot)*	Ration gilts were fed during gestation and lactation	Litter Record					
			No. of sows	No. sterile gilts	No. pigs farrowed	No. pigs weaned	Percent pigs weaned	Average weaning weights at 56 days
			1945					
1	Tankage+5% alfalfa	Tankage+5% alfalfa (dry-lot)	3	1	19	5	26.3	33.4
3	Peas+5% alfalfa	Peas+5% alfalfa (dry-lot)	3	2	8	0	0	0
4	Peas+15% alfalfa	Peas+15% alfalfa (dry-lot)	3	0	26	13**	50.0	23.1
			1946					
8	Peas+5% alfalfa	Peas+20% alfalfa (dry-lot)	4	1 (See table 3)	21	1	4.8	19.3
10	Peas+15% alfalfa	Peas+20% alfalfa (dry-lot)	4	0	28	17***	60.7	24.2
11	Peas+15% alfalfa	Peas+20% alfalfa (pasture—half alfalfa and half wheat)	4	0	27	15****	55.6	24.8

* Wheat, barley and minerals made up the rest of the ration. All rations contained 16% total protein during gestation and lactation.

** One sow had 7 nice looking pigs but was mean and killed them by the second day.

*** One litter of 8 pigs was chilled at birth due to lack of attendant.

**** One litter of 6 pigs was chilled at birth due to lack of attendant.

duction and lactation with the gilts fed tankage as a protein supplement. The data also show that the gilts fed 15 percent alfalfa (cull peas as protein supplement) performed much better than the gilts fed only 5 percent of alfalfa, (cull peas as protein supplement). With the gilts fed 5 percent of alfalfa, no pigs were weaned and two-thirds of the gilts were sterile, whereas, all the gilts fed 15 percent of alfalfa in the ration conceived and in addition weaned 50 percent of their pigs.

The data obtained during 1946 (table 2) show a decided advantage for feeding 15 percent of alfalfa as compared to 5 percent alfalfa in the ration during growth to prospective herd gilts. The gilts fed 5 percent alfalfa during growth (lot 8) performed much poorer than those gilts fed 15 percent of alfalfa during growth (lot 10), in spite of the fact that both lots of gilts were fed the same ration during gestation and lactation. The gilts in lot 8 (5% alfalfa during growth) only weaned one pig, whereas in lot 10 (15% alfalfa during growth) a high percentage of the pigs, 17 out of 20 (when excluding the sow whose pigs were chilled at birth), were weaned. This certainly demonstrates a storage, or carry over, of a factor or factors during the growth period of gilts which is of much importance later during reproduction and lactation.

The data given in table 3 further demonstrate the value of a higher level of alfalfa during the growth period. In lot 10 (15% alfalfa during growth), not much difficulty was observed in getting the animals to conceive. How-

TABLE 3. LENGTH OF TIME IT TOOK GILTS TO CONCEIVE DURING 1946 TRIALS

Lot No. from which gilts were taken	Ration gilts were fed during growth (in dry-lot)	Ration gilts were fed during gestation and lactation	Gilt numbers	A boar was kept with the gilts all the time. Following is the heat period at which the gilts conceived	No. of days after boar was turned in before gilts conceived
8	Peas+5% alfalfa	Peas+20% alfalfa (dry-lot)	635	2nd	33
			630	7th	134
			627	9th	172
			602	Bred 11 times. Still coming in heat when slaughtered	226 (still no conception)
10	Peas+15% alfalfa	Peas+20% alfalfa (dry-lot)	661	1st	17
			662	1st	10
			660	2nd	39
			631	3rd	65
11	Peas+15% alfalfa	Peas+20% alfalfa (pasture—half alfalfa and half wheat)	626	1st	17
			645	1st	12
			671	1st	16
			656	1st	7

ever, in lot 8 (5 percent of alfalfa during growth but fed the same ration as in lot 10 during gestation and lactation), considerable difficulty was experienced in getting the gilts settled. As is shown in table 3 in lot 8, one gilt conceived during the second, one during the seventh, and one gilt during the ninth heat period. In addition, one gilt had been bred eleven times and had still not concived when slaughtered. In other words, ability to conceive was impaired due to the fact that these gilts received only 5 percent of alfalfa during growth. This difficulty was not encountered with gilts fed 15 percent of alfalfa during growth. These data are in line with those of Cunha *et al.* (1944) which showed that the ration fed during growth has a very definite effect on results obtained later during reproduction and lactation.

The data presented in table 2 show no difference between the results obtained with gilts on pasture versus no pasture (lots 10 and 11). The pasture, which was not too good, lasted for only 3 months. The gilts were started on pasture 3 weeks before they were bred. The data show that, with gilts fed 15 percent of alfalfa during growth and 20 percent of alfalfa during gestation and lactation, the pasture used was of no apparent benefit. It was also found that no difference in storage of factors occurred in the small pigs of the sows fed pasture (lot 11) versus those of the sow not fed pasture (lot 10). No difference in growth of the young pigs from the sows has been observed in three different rations, when one half of the pigs fed in each lot were from gilts fed pasture (lot 11) and the other half of the pigs are from gilts not fed pasture (lot 10).

Discussion of Results

Beeson and Hickman (1945, 1946) and Lehrer and Hodgson (1946) reported that ground peas as a protein supplement did not give as good results as when some meat meal was included in the ration. The work reported herein shows that cull peas compared very favorably to meat meal as a protein supplement. The different results obtained at the Idaho station are most likely due to the fact that they self-fed their rations free-choice and as a result the protein content of the various rations was not kept constant and the intake of alfalfa in the different rations varied from approximately 1.5 to 5.0 percent. In the work reported herein the percentage of the various ingredients and the protein content was kept constant in mixed rations.

The data presented show that the ration fed during growth has a marked effect on conception, reproduction and lactation with the pig. It demonstrates that a storage of dietary essentials needed for reproduction and lactation takes place during growth. These results are in agreement with those of Cunha *et al.* (1944) with swine, and Cunha (1944) and Spitzer and

Phillips (1946) with rats. These results stress the importance of knowing the previous ration fed animals and to evaluate accordingly. The data obtained also stress the need for feeding higher levels of alfalfa during growth to prospective herd replacement gilts. A pork producer certainly could not afford to wait from 5 to 8 months to get gilts to conceive such as occurred with some of the gilts fed only 5 percent alfalfa during growth. In addition, those gilts fed only 5 percent of alfalfa during growth lost most of their pigs shortly after parturition.

Summary and Conclusions

Cull peas compare very favorably with meat meal and soybean oil meal as a protein supplement for growing-fattening pigs fed in dry-lot. At prevailing feed prices, when these experiments were conducted, the pigs fed cull peas made by far the cheapest gains.

In these trials, the pigs fed meat meal as protein supplement developed an exudate on the surface of the body which resembled, but was not, mange. In the 1946 trials it was found that this skin condition later cleared up when the pigs were turned out to pasture. None of the pigs fed cull peas developed the abnormal skin condition.

The rate of gain was lowered to a small extent when the alfalfa content of the ration was increased from 5 to 15 percent during the growing-fattening period. However, it was shown that pigs fed 15 percent of alfalfa as compared to 5 percent alfalfa during growth stored a factor or factors which later influenced conception, reproduction, and lactation. The pigs fed 5 percent of alfalfa during growth took much longer to conceive, some of the gilts became sterile, and only a few pigs were weaned. When 15 percent of alfalfa was fed during growth, it took considerably less time for the gilts to conceive, no sterility was encountered, and quite a high percentage of the pigs were weaned.

Data are presented to show that the ration fed gilts during growth has a very important bearing on results obtained later during conception, reproduction and lactation. This means that prospective herd gilts need to be fed much better rations, especially higher in alfalfa, during growth than animals being fattened out for market.

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NUTRIENT UTILIZATION BY "COMPACT" AND CONVENTIONAL TYPE SHORTHORN STEERS[1]

L. E. Washburn, Johnny Matsushima, Herman F. Pearson, and R. C. Tom[2]

Colorado Agricultural and Mechanical College[3]

RECENT show-ring winnings by "Compact" Shorthorns and "Comprest" Herefords have incited much interest in the influence of body type on animal economy. Performance of such examples of the cattle breeder's art as these extremely compact individuals seems not to have received adequate mention in the literature concerning beef production as related to body type and size (Hultz, 1927; Hultz and Wheeler, 1927; Lush, 1932; Winters and McMahon, 1933; Black and Knapp, 1936; Kleiber, 1936; Branaman and Brown, 1936–37; Black, Knapp, and Cook, 1938; Woodward, Clark, and Cummings, 1942; Guilbert and Gregory, 1944; Knapp and Baker, 1944; Brody, 1945). Extremely compact type cattle are apparently the result of a different genetic pattern (Lush, 1930; and Stonaker and Tom, 1944), and consequently do not fit into the conventional type variation observed in ordinary cattle populations.

This paper deals with a preliminary digestion balance (Ritzman and Benedict 1929) study of food utilization by three pairs of Shorthorn steers from three different herds. Each pair consisted of a conventional type and a compact type animal which were selected from the progeny of the same bull. All animals of the three pairs were born within a period of nineteen days.

Procedure

The period of investigation was arbitrarily divided into a growth and a fattening phase, the division occurring when the animals were about eleven months of age. During the growth phase, all animals were kept in the same lot and fed the same growth ration, made up of concentrates in the morning and hay and silage at the night feeding. In the fattening phase the compact and conventional types were separated, each group receiving *ad libitum* the same fattening ration, consisting of grain twice each day, wet beet pulp in the morning, and hay at night. The animals were given water before each feeding during the entire experiment.

All animals were subjected at the same time to periodic digestion balance

[1] Scientific journal series article No. 228 Colorado Agricultural Experiment Station.

[2] R. C. Tom was formerly head of Animal Investigations Section, Colorado Agricultural Experiment Station, now associated with Ralston-Purina Company, St. Louis, Missouri. To Dr. S. S. Wheeler, who became head of the Animal Investigations Section after this work was completed, the authors wish to express their appreciation and gratitude for his interest in the study and for his expert advice during preparation of the manuscript.

[3] Animal Investigations Section, Ft. Collins, Colorado.

trials of twenty days duration. Each trial was divided into two ten-day periods separated by three or four days during which the animals were removed from digestion balance stalls to the lot for weighing and exercise. Ration components, urine, and feces were sampled daily during each twenty-day period. Urine samples were preserved with toluene in stoppered bottles and feces samples, preserved with chloroform, were kept in galvanized metal cans with tight fitting covers. All composite samples were stored in a cool, dark place until analyzed by currently accepted methods for dry matter, nitrogen, calcium, and phosphorus. Two balance trials were completed for all animals during the growth and again during the fattening phase. A third digestion trial was carried out with the conventional type steers shortly before they were marketed.

The rations fed during this experiment were as follows:

Growth Phase		*Fattening Phase*	
Roughage:	(40.92%)	Roughage:	(15.90%)
Chopped Alfalfa hay		Chopped Alfalfa hay	
Corn Silage		Grain Mixture:	(84.10%)
Grain Mixture:	(59.08%)	Coarse Ground Corn—	38.5 parts
Coarse Ground Corn—	78.5 parts	Rolled Barley	38.5 parts
Whole Oats	14.3 parts	Whole Oats	7.7 parts
Soybean Meal	7.2 parts	Beet Pulp[4]	7.7 parts
		Cottonseed Meal	3.8 parts
		Soybean Meal	3.8 parts

Following slaughter and after carcasses had remained in the cooler for several days, two standard butcher's cuts (round steak and club steak, 13th rib—see figures 2 and 3) were taken from each carcass for analysis. The meat samples were transported to the laboratory in a container cooled with dry ice, and were kept frozen and exposed in a refrigerator until considerable dehydration had taken place. Meat and bone were then cut into small cubes which were repeatedly extracted with petroleum ether until most of the fat had been removed. The cubes were then dried further in a low-temperature, forced-air dryer and were ground in a Wiley mill. Fat extraction and moisture analysis were completed on the ground samples. Nitrogen and ash determinations were made on fat-free samples.

Results

While compact animals deviated considerably from the conventional body type as judged visually, digestion balance data showed little variation between the types with respect to digestibility of feed constituents. Digestibility as measured by dry matter, nitrogen, and ash analyses, within both types was greater during fattening than in the growth phase. These results seem not to be in agreement with the commonly held opinion that increasing

[4]Fed separate and wet.

food intake is accompanied by a decline in digestibility. However, the probability of increasing digestive capacity must be considered. Assuming that alimentary tract weight increases at a rate about ninety percent that of body weight change during growth (Brody, 1945), then computation shows a relative digestive tract increase of about seven percent per unit of food intake for both steer types. Data shown in table 1 for apparent digestibility of dry matter obtained by direct analysis indicate an equivalent change. Also, the increasing rate of digestibility may in part be explained by the fact that, because of change in quality of hay, protein content of the rations increased slightly but constantly throughout the experiment.

TABLE 1. METABOLIC DATA—DIGESTION BALANCE TRIALS WITH "COMPACT" AND CONVENTIONAL TYPE SHORTHORN STEERS*

Digestion trial no.	Type**	Weight	Daily dry matter intake (Per 100 lbs. body weight)	Daily gain	Apparent digestibility: D.M.	Apparent digestibility: Nitrogen	Apparent digestibility: Ash	Daily retention (Total): N	Daily retention (Total): Ca	Daily retention (Total): P
		lbs.	gms.	gms.	per cent	per cent	per cent	gms.	gms.	gms.
Growth Phase										
I	A	403	1029	205	78.0	58.8	60.89	18.9	6.8	5.5
	B	444	998	221	77.9	58.8	62.34	20.0	8.1	6.5
II	A	529	869	133	82.1	67.8	68.20	20.4	9.0	5.3
	B	605	867	146	82.7	68.8	72.58	22.6	11.8	6.8
Fattening Phase										
I	A	687	855	107	85.5	65.8	66.5	25.0	12.0	6.4
	B	826	855	131	85.6	66.1	67.3	24.0	15.3	8.2
II	A	727	845	99	84.6	69.4	64.6	45.0	15.6	4.4
	B	883	816	88	85.0	74.4	65.6	48.4	15.8	5.7
III	B	1043	665	86	86.2	79.2	74.7	55.3	8.2	9.7

* Each figure is an average for three animals.
** A—Compact Type; B—Conventional Type.

Although both types of steers showed close similarity insofar as feed capacity and digestibility were concerned, quite different results were observed with regard to utilization of digested nutrients. Figure 1 indicates that the conventional type animal during the growth phase deposited as gain a greater percentage of digested dry matter than did the compact type. This difference was of the order of twenty-five percent when the animals were compared on a weight-constant basis, or thirteen percent when data

were plotted at equivalent age. It is interesting to note that at the time animals of either type were visually judged finished for slaughter, the values had converged to a similar level, about thirteen pounds gain per hundred pounds digested dry matter. The compact animals during fattening showed a lower rate of decline in efficiency of conversion than did the conventional type.

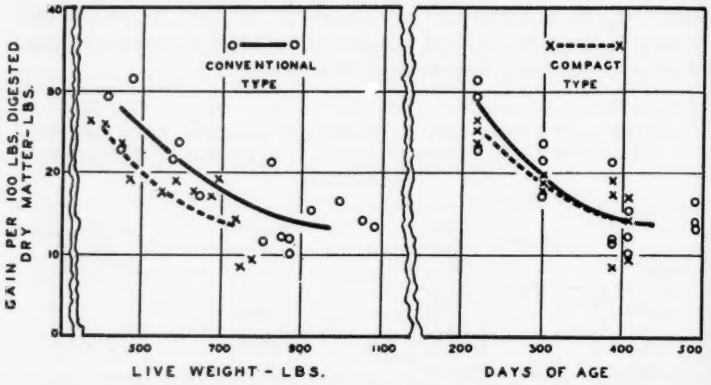

Figure 1. Gain per unit digested dry matter. Curves drawn through points obtained by averaging individual data for each balance trial, and plotted on weight-constant and age-constant bases.

While the same data were used for both sets of curves in figure 1, plotting was done on both weight-constant and time-constant bases in view of the current debate as to whether animal performance should be evaluated at equivalent weight or age. The authors believe that published evidence justifies the comparison of physiologic data on an age-constant basis. Observations reported in this paper indicate that a more critical evaluation of the behavior of different type animals is possible when judged at the same age.

That the "compact" or "comprest" type animal may be an endocrine anomaly is suggested by these data. The compact and conventional animals differed essentially in the metabolism and deposition of digested material as body substance and not with respect to food capacity or digestibility of nutrients. That such difference in deposition was not entirely due to degree of fattening was shown by the development in the compact type animals of prominent shoulders ("heifer chuck"), lacking flesh covering in proportion to bone. That was, in fact, the only criticism made by the packer for the compact type carcass. One of the compact animals developed prominent

shoulders immediately following a transient stiffness and lameness of rather severe nature. This condition, observed frequently in varying degree in heavily fed cattle, is believed following several years study at this station (unpublished work) to be intimately associated with the endocrine system.

All carcasses were graded "choice" by the packer. Data in table 2 show that differences between compact and conventional type carcasses were

TABLE 2. CARCASS DATA—"COMPACT" AND CONVENTIONAL TYPE SHORTHORN STEERS.* PERCENTAGES DRY MATTER, ETHER EXTRACT, PROTEIN AND ASH ARE ON A FRESH BASIS

Type	Carcass cut	Fresh weight	Moisture	Dry matter	Ether extract	Protein (N×6.38)	Ash
		gm.s	*percent*	*percent*	*percent*	*percent*	*percent*
Compact	Round	1028	62.0	38.0	18.4	16.6	2.4
	Rib	1241	43.8	56.2	36.3	14.1	5.5
Conventional	Round	2354	59.6	40.4	20.1	17.2	2.1
	Rib	1516	38.8	61.2	44.8	10.3	4.5

* Each figure gives average of three individual cuts.

mainly degree of fattening and ash content. Fat percentage was greater on the conventional type cuts while the "compact" cuts yielded higher ash content. Rib cuts showed more pronounced differences than did the rounds. The relatively heavier bone in the compact type carcass is plainly evident in figures 2 and 3.

Data shown in table 3 summarize feed-lot and slaughter results. The greater efficiency of food utilization by conventional type animals is again revealed in the feed cost of one hundred pounds gain. It must be pointed out, however, that data given in table 1 and figure 1 were obtained with the animals confined in digestion balance stalls, while that in table 3 represents the overall feeding period of the animals in the feed-lot. Moreover, total cost and net loss items in table 3 reflect the weight of labor, insurance, and interest factors. Although the conventional type steers proved more efficient in the utilization of feed, seventy days longer feeding period was required to attain slaughter condition similar to that shown by the compact animals.

Summary and Conclusions

Nutrient utilization by Shorthorn steers of "compact" and conventional types was investigated by means of digestion balance trials and analysis of standard carcass cuts following slaughter.

Limited data of a preliminary nature showed no appreciable difference be-

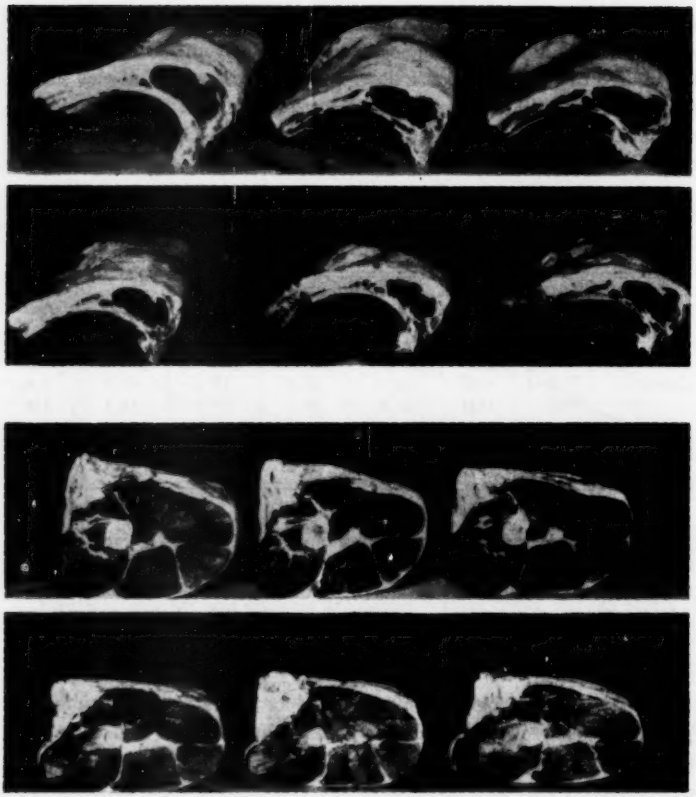

Figure 2. (Top) Rib cuts from "Compact" (upper) and Conventional (lower) Shorthorn Steer carcasses.

Figure 3. (Bottom) Rounds from the same caracsses. The relationship of bone, flesh, and fat, and degree of marbling are clearly shown, although slightly different focal distances were unavoidable in photography.

tween steer types with respect to food capacity per unit of body weight and digestibility of nutrients. Conventional type animals, however, exhibited greater ability than "compacts" to utilize digested dry matter during growth. A rapid decline in efficiency of gain from growth to fattening was observed for both types, each reaching the same level at the time the animals were visually judged finished. Seventy days longer feeding was required to finish the conventional type animals.

TABLE 3. SUMMARY OF FEED-LOT AND SLAUGHTER DATA—"COMPACT" AND CONVENTIONAL TYPE SHORTHORN STEERS

Items compared	Average of "compacts"	Average of conventionals
Initial weight, lbs.	308.0	343.3
Shipping weight, lbs.	725.0	1068.3
Market weight, Denver, lbs.	716.7	1036.7
Days on feed: Growing	169.0	169.0
Fattening	117.0	187.0
Total	286.0	356.0
Daily gain, growing, lbs.	1.5	1.7
Daily gain, fattening, lbs.	1.7	2.3
Daily gain, overall average	1.5	2.0
Initial cost, ($13.00/cwt.)	$ 40.08	$ 44.63
Feed cost per 100 lbs. gain:		
Growing	$ 14.41	$ 13.51
Fattening	$ 19.16	$ 17.96
Average	$ 16.48	$ 16.14
Total cost	$125.09	$180.13
Market price ($16.75/cwt.)	$120.04	$173.64
Net loss	$−5.05	$−6.49
Swift & Co. grade*	2 Premium 1 Select —	1 Premium 1 Select 1 Liner select
Individual finish, rank*	1, 2, 4	3, 5, 6
Estimated price, per 100 lbs.*	$ 16.67	$ 16.50
Shrink to market, percent	1.15	2.96
Warm carcass weight, lbs.	460.3	660.7
Cold carcass weight, lbs.	452.0	648.8
Dressing percent	63.0	62.6
Carcass grade	Choice	Choice

* Steers graded on finish and priced August 2, 1944, one day before "compacts" were shipped to Denver for slaughter. Conventional type steers slaughtered October 13, 1944.

All carcasses were graded choice. Conventional type cuts carried more fat, and the compact type carcass had relatively heavier bone.

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RECORD OF PROCEEDINGS OF THE THIRTY-NINTH ANNUAL MEETING OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

THE thirty-ninth annual meeting of the American Society of Animal Production was held at the Hotel Sherman in Chicago on November 28 and 29, 1947, and a dinner for the honor guest was held at the Stockyard Inn on November 30. Abstracts of most of the papers presented were published in the November, 1947 issue of the JOURNAL OF ANIMAL SCIENCE, volume 6, pages 466–503.

DEVELOPMENTS IN THE SCIENCE AND PRACTICE OF ANIMAL PRODUCTION

W. A. CRAFT

President, American Society of Animal Production

DURING the 39 years since the Society was organized there have been tremendous developments in the application of technology in agriculture and other industries. These developments are largely examples in the application of research. Many of the advances have been in the field of animal production and numerous members of the Society have contributed to this progress through their research or by applying the breeder's art. It seems appropriate to recount a few of the developments in our field.

Methods of processing protein supplements have been advanced greatly. Improvements in feeding practices include extensive use of protein supplements, minerals and feeds rich in certain vitamins. Discovery and use of knowledge relating to vitamins, proteins and minerals gained through animal feeding investigations constitutes a major achievement.

Development of the feed industry is an example of industrial application of discoveries in the field of animal nutrition. Likewise improvements in processing meat and meat products are examples of industrial application of results from research laboratories. These improvements have contributed directly or indirectly to advances in animal production.

During the period since the Society was organized there have been discoveries and developments in the science of breeding. These relate to: (1) the nature of differences between breeds; (2) the effectiveness and limitations of phenotypic selection; (3) the usefulness and limitations of progeny tests, and selective registration; (4) the unraveling of information regarding the genetics of populations of animals; (5) the development of selection schemes such as indexes; (6) estimates as to the heritability of various physiological characters; and (7) the usefulness and limitations of artificial insemination.

Breeding practices have been developed and applied with skill in bringing about changes in conformation and rate of maturity of animals.

Hogs now attain market weights at an earlier age than formerly. Production per sow has increased a little. Butter fat and milk production of cows have increased. Improvements have been made also with beef cattle, sheep and poultry. These changes have played an important part in livestock production.

Advances in nutrition in respect to several factors were slow until the aid of scientists in other fields was enlisted. Identification and the effects of various vitamins lagged until the organic chemist attacked the problem of isolating and synthesizing these factors. The development of knowledge regarding the vitamin and amino-acid content of feeds is being speeded up by the use of microbiologic and spectroscopic methods; and still more recently the use of radio-active elements is being explored in studies with animals. The use of synthetic products in animal feeding is being investigated.

Perhaps, in the future, the livestock producer may gain increased control over the growing and fattening processes of animals. Thus he might have a quicker response to his effort with respect to the development of form and finish of meat animals than he now enjoys.

Similarly the livestock producer may be aided further some day by new discoveries from genetic investigations.

Noteworthy progress has been made with respect to control of certain diseases among livestock. We express gratitude to the veterinarians for the party they have played in this achievement. There are unconquered foes in this field, however, which challenge all groups in the animal sciences.

This has been a period of development and growth of professions and their various societies. Animal husbandry has become a profession. Its prestige among other professional groups is a matter of concern to us. In the broad field of animal husbandry the Society is the representative of research men, teachers, extension workers and livestock producers. The strength of the Society and the service it can perform depends on our realization of a professional pride, and our willingness to accept responsibility, individually and collectively with respect to our profession.

Animal production and the processing and merchandising of animal products constitute major industries in our economics. These industries are contributing much to our general national well-being. Continuous progress of the animal industry will require not only research in all phases of agriculture but also alertness in applying the results of research findings. This is an era of technology in all industries. The various industries are competitive. Those that survive are likely to be those in which new discoveries are

applied speedily, but wisely to improve efficiency. Problems arising out of the recent war and our efforts in meeting them require adjustments. These adjustments should be based on sound procedures. Cooperation of various groups will be needed. Interrelationships of various enterprises should not be ignored.

Today we are to survey the general problem of animal production and a long-time land use and conservation policy with respect to the economic, social and nutritional well-being of the people in the United States. Speakers have been selected to focus our attention on four general aspects of the subject. Through the discussion today it is hoped that we may improve our perspective, regarding the relationship of animal production to agriculture as a whole, and the general well-being of the people of the country. (This was followed by the presentation of four papers, as follows: "The National Land Use and Conservation Policy" by R. M. Salter of the U. S. Department of Agriculture; "Changes Expected as to Kind, Quantity, and Quality of Feeds" by E. A. Trowbridge of the University of Missouri; "Adjusting Animal Populations, Feeding and Management Practices" by F. B. Morrison of Cornell University; and "Changes Expected in Animal Production in the South" by J. H. Hilton of North Carolina State College. Mimeographed copes of these addresses may be obtained from the authors.)

SUMMARY OF MINUTES OF THE THIRTY-NINTH BUSINESS MEETING OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

W. G. KAMMLADE, *Secretary*
University of Illinois

THE meeting was called to order by President W. A. Craft at 2:20 P.M. November 29, 1947, at the Hotel Sherman, Chicago. One hundred and twenty-seven members were present.

The reading of the minutes of the previous meeting was not called for as a summary of these had been published. In reading the minutes of the Executive Committee meeting the membership was advised of a fifty-cent increase in dues and subscriptions for 1949 and that W. G. Kammlade had been appointed Business Manager of the JOURNAL OF ANIMAL SCIENCE.

The Treasurer reported receipts totalled $10,049.31 including $3,000 in The Morrison Award fund. This amount and the balances on hand on November 1, 1946, made a total of $19,815.27. The publishing of the JOURNAL OF ANIMAL SCIENCE, investment in United States bonds, and the 1946 Morrison Award represented the largest items of expense. Total expenditures were $13,351.85. The cash balance on October 31, 1947, was

$6,463.42. The Society's bonds have a current value of $9,122.20.

B. H. Schneider, Leslie E. Johnson and A. L. Harvey, acting as an Auditing Committee reported the Treasurer's books and accounts in order.

The Secretary reported the total membership on October 31, 1947 was 879; 824 in the United States and 55 in other countries. He reported 487 registered in attendance at the 1947 meetings. During the year the office handled 7,194 pieces of Society mail.

As Business Manager of the JOURNAL OF ANIMAL SCIENCE, the Secretary reported the mailing list totalled 1,316, a gain of 263 over 1946.

The Nominating Committee's report was accepted, and the following officers were elected: Paul Gerlaugh, President; W. G. Kammlade, Vice President; and H. M. Briggs, Secretary-Treasurer.

The Secretary informed the Society that the survey concerning Honor Guests showed almost a four-to-one preference for one Honor Guest a year

The Committee on Investigations reported that some recommendations by earlier committees had not been carried out and that it renewed some of these recommendations. Its recommendations included the appointment of a Monograph Editorial Committee to work with the Editorial Board of the JOURNAL OF ANIMAL SCIENCE for the purpose of publishing books of interest to the Society. Two titles were suggested for early consideration:

(1) Role of Livestock in Land Utilization for Food Production

Recurrent emphasis on more efficient use of land for production of human food would seem to justify a critical appraisal of the usefulness of livestock in food production. The importance of this subject was emphasized in the Opening Session of this year's meeting. In fact, the information presented this year might form a basis for a more comprehensive treatise of this subject; namely, the role of livestock in land utilization for food production.

(2) Pasture and Range Investigations

This monograph should be a critical review and summary of pasture and range investigations with the various classes of farm animals and poultry. Such a book would be useful as a reference work for young investigators, for teachers and extension men, and it would focus attention on the needs for further research.

This committee also mentioned the importance of papers on experimental design, techniques, analyses and presentation of data and suggested such papers be invited in various sections of the program.

The Committee on Instruction charged with the responsibility of the teaching section made the following suggestions: (1) that the program begun this year be continued, (2) that next year's program might include a discussion of genetics, physiology, biochemistry and nutrition, (3) that the following year the Society discuss the application of chemistry, zoology, mathematics, genetics, physiology and nutrition to the problems of animal production, (4) that eventually the Society might suggest minimum require-

ments of the various underlying sciences, such as chemistry, zoology, et cetera, for animal husbandry students, and (5) a study of graduate programs for animal husbandry students.

The Extension Committee made no report. The following were chosen by those attending the Extension Session to be on the committee and help prepare the program for 1948: M. W. Muldrow, chairman; George R. Johnson, and Grady Sellards, secretary.

Paul Gerlaugh reported for the Membership Committee. He reported 185 new members during 1947.

H. R. Guilbert, chairman of the Special Committee on Time and Place of Meeting, reported 343 members returned questionnaires and that a tabulation of the ballots showed:

(1) In favor of meeting regularly in Chicago	225
a. On Friday and Saturday, as in the past	143
b. Meeting last 2 or 3 days of International Week	74
c. Meeting at Chicago at some other time	8
(2) Meeting at other city, or cities, in rotation	15
(3) Meeting at Land Grant Institutions	
a. During summer	92
b. Alternating at Chicago and Land Grant Colleges	7
(4) Duration of meeting	
a. 2-day meetings	169
b. 3-day meetings	114

The Committee also reported that it was advisable to explore further the possibility of meeting in Chicago on alternate or every third year and meeting elsewhere at other times. The report was accepted and the committee discharged.

The Committee on Pasture and Range Investigations made no report although attention was called to the need of improvement in research. On motion and vote the committee was continued.

The Committee on History of Livestock made a lengthy report outlining objectives and recommending the establishment of a new office in the Society. The main parts of the report which was accepted were:

Objectives

(1) To preserve in narrative form the purposes, objectives, methods of procedure, and significant incidents in originating and developing new breeds of sheep, swine, cattle, horses, and other domestic animals—either under public auspices or in private hands.

(2) To assemble and preserve *references* to the original data in the files of the federal and state experiment stations, of similar institutions, or in private hands, at which new breeds or methods of breeding were developed, and on which the suggested narratives, described in paragraph one, are based.

(3) To assemble in orderly manner, and to analyze as thoroughly as possible, facts regarding the grading-up and improvement of the commercial flocks and herds of livestock.

(4) To assist in the publication of the results of such studies in appropriate books or scientific, historical, agricultural, livestock, and other journals, according to the nature of the material and the type of special or public interest.

Historical Organization

(1) It is recommended that the Office of Historian be created for the Society, and that a historical committee be appointed to work with the historian.
(2) The following duties are suggested for the historian:
   a. To serve as chairman of the Committee on History of Livestock.
   b. To outline the field of study.
   c. To cooperate with the workers at the different stations so as to secure as complete a set of narratives as possible for the Society.
   d. To serve as custodian of the narratives and published materials, and to provide a record of reference to the location of data on which the historical narratives are based.
   e. To assist in securing the publication of the narratives and other reports of the Committee.
   f. To point out segments of breed history and livestock improvement that are less well known, and by suggestion and stimulation of appropriate workers, to cover such fields.
   g. To assemble a bibliography of livestock history, appropriate to the purposes of this committee, and to arrange for its publication at appropriate times, either in the journal of the American Society of Animal Production, or in a separately published brochure of the Society.
   h. To build up and arrange suitable records regarding the established breeds, and to reorganize them periodically in the light of genetic, physiological, nutritional, and general scientific advancement.
(3) The historian of the Society could best be one of the professors of animal husbandry who is familiar with, and who has lived through, most of the period of development of modern science in the agricultural colleges. Quite a number of such men are retiring or being placed on the meritus list, but are in such good physical health that they could take charge of the original organization of this work.
(4) The members of the historical committee should be individuals specializing in particular species of livestock, or in particular studies of livestock breeding. To begin with, it is suggested that persons with specific interest in swine, sheep, cattle, and horses, be included, and that a geneticist, a nutritionist or physiologist, a livestock economist, or perhaps one or two other specialists be appointed to the committee.
(5) In order to provide continuity of policy and procedure, it is recommended that the term of service for the historian be four years, and that the terms for members of the committee be three years—the latter to be divided into three groups, with a term of one group expiring each year. The first appointments to the committee would be for one, two, and three years, for each of the three groups.

The report of the Committee on Information showed many papers were using the material prepared covering news and activities of the Society and its members. An incomplete record showed 74 papers used 200 news items. Radio stations also featured some of the Society's activities.

E. A. Livesay requested suggestions regarding subjects which might be

discussed by the Inter-Association Council. No meeting had been held during the year.

The Society's representative on the Council of the American Association for the Advancement of Science, F. F. McKenzie, made no report.

Hugh C. McPhee reported on activities in connection with legislation to establish a National Science Foundation and suggested this Society be represented. His suggestion was adopted.

Attention was given to the Institute of Biological Sciences and whether the Society should become a member of Institute. Paul Weiss, Professor of Zoology of the University of Chicago, explained the purroses, types of memberships, and organization of the Institute and stated that through it Biological Sciences would be given greater voice in many matters. The fee would be one dollar per member. Professor Weiss said that many secretarial duties of member organizations would be done in a central office. It was moved that the Society forego becoming a charter member of the Institute and that a committee be appointed to give consideration to all matters concerning membership in the Institute. The motion carried.

The Society's representative on the National Research Council's Division of Biology and Agriculture, H. W. Marston, reported that the group had discussed the Institute of Biological Sciences. Dr. R. F. Griggs had resigned as chairman of the Division and a successor had not yet been appointed.

The Editor of the JOURNAL OF ANIMAL SCIENCE summarized the Society's publication activities and problems as follows:

A total of 334 manuscripts had been submitted for consideration for publication in the JOURNAL up to November 30, 1947. Of these, 270 were published in Volumes 1 to 6, 16 were in press for the February, 1948 issue, 27 had been refused publication or had been withdrawn by the authors, and 21 were ready for the printer or were in various stages of editing. Publication during 1947 included 49 manuscripts, the President's address and other Society proceedings of the 1946 meeting, 78 abstracts of papers to be presented at the 1947 annual meeting of the Society, subject and author indexes of Volume 6, and the usual News and Notes section in each of the four issues.

The increase in number of manuscripts submitted has been substantial (71 during the past year, compared with 42 during the previous year), and this is reflected in the status of publication. When reporting one year earlier it was possible to state that when the February, 1947 issue was sent to press only one manuscript upon which editing has been completed remained in the files. That is typical of the situation that had existed since the JOURNAL was established, but a different situation now exists. When the February, 1948 issue went to press, 11 edited manuscripts remained in the files and the number in process of being edited was larger than usual. These figures, plus the facts that 49 manuscripts were published in 1947, compared with 41 in 1946, and that an unusually large number of manuscripts (16) is in press for February, 1948, should indicate to the members of the Society that the burden of publication is increasing and that serious attention must be given particularly to the financing of the JOURNAL. This situation may reflect to some extent a shift in the seasonal production of papers, representing an attempt on the parts of authors to get papers in ahead of the rush that has usually fol-

lowed the annual meeting. However, it seems likely that it is the first major upswing in production of scientific papers that seemed inevitable after many workers returned from wartime activities and could again turn their attention to research.

Printing costs will also be higher in 1948, owing to an increase of approximately 20% in the rates for this work, without regard to the increase in volume.

The recommendation that the Secretary publish, perhaps in alternate years, a membership list, as a separate folder and distribute this to the members was adopted.

Paul Gerlaugh presented and the Society accepted the following resolution regarding the continuation of The Morrison Award:

Whereas, Frank B. Morrison and Elsie B. Morrison of Ithaca, New York, have provided to the American Society of Animal Production funds to make possible the granting during a five-year period ending in 1950 of an annual award, known as the Morrison Award, which Award was established by them to promote scientific advancement in the field of Animal Husbandry and thus promote human welfare, and the Award each year during this period is to be made to a member of the Society who shall have made a meritorious scientific contribution or discovery in research in the field of Animal Husbandry, the recipient being selected by a special Award Committee of the Society appointed by the officers; the Award being further subject to the provision that no individual shall receive the Award more than once; that selection shall be made without respect to race, sex or age; and that the donors shall in no way influence the selection of the recipients, and

Whereas, said Frank B. Morrison and Elsie B. Morrison propose to establish a trust fund, the income of which is to be used for the continuance of the Award by the American Society of Animal Production, now therefore be it

RESOLVED: That the American Society of Animal Production recognizes that such Award promotes scientific advancement in the field of Animal Husbandry and encourages meritorious scientific contributions and discoveries, and thus promotes human welfare, and be it further

RESOLVED: That the Executive Committee of this Society be and hereby is authorized to accept the establishment of such trust fund for the continuance of said Award, and to do any and all other things deemed beneficial in connection with the administration thereof, and be it further

RESOLVED: That the Society hereby agrees that if a trust fund is established by the said Morrisons for the continuance of such annual Award after 1950, it will administer the granting of the Awards on the general basis hereinbefore stated and in such amounts as may be available by income from the trust fund or by gift, and that it will undertake to perform such acts as may be necessary or advisable in the opinion of the officers of the Society in furthering the purposes of such Award. It further agrees to notify from time to time the Trustee of such fund concerning the names of the officers of the Society who shall be authorized to receipt for the amounts available for such Award and to do any and all other things necessary in connection with the administration thereof.

The Executive Committee recommends that the Society accept the plan and extend an expression of thanks to Professor and Mrs. Morrison for their thoughtfulness and generosity in behalf of the science of Animal Production and thus human welfare.

D. E. Brady discussed the Society's program and then moved that a section devoted to Meats and Meat Products be made a part of the annual meeting. The motion carried.

The Secretary reported that, in a letter dated February 25, 1947, Dr. O. B. Kent, Chairman of the Nutrition Council of the American Feed Manufacturers Association advised that the Association proposed three awards of $1,000 each annually for a three-year period for work in the fields of livestock and poultry nutrition, one award to be made each year through the American Society of Animal Production, one through the Dairy Science Association, and one through the Poultry Science Association. After further correspondence representatives of these three Associations met with the Award Committee of the Nutrition Council and agreed to the following general terms:

(1) Candidates residing in United States and Canada are eligible.
(2) Research work published in 1946 and 1947 will be considered for the 1948 award; 1947 and 1948 for the 1949 award; and 1948 and 1949 for the 1950 award.
(3) Eash association will make its own selection, set its own rules with the thought of having the rules as uniform as possible—one prize for each association.
(4) Only research work done at public institutions, hospitals, and similar organizations will be considered.
(5) Work must be original on animal and poultry nutrition.
(6) Prize winners will be awarded the money at the regular meeting of each association and honored at the regular meeting of the American Feed Manufacturers' Assn. the following spring. Some representative of the A.F.M.A. and Nutritional Council will be present at the meetings of the associations when the awards are made.
(7) The A.F.M.A. will present a certificate and perhaps some token when honoring the winners.
(8) The American Society of Animal Production award would be for work on animals other than dairy cattle or poultry.

The Society voted to accept the awards offered for administration by it and to thank the American Feed Manufacturers Association for making the funds available.

Ralph W. Phillips called attention to the proposed organization of an International Association of Animal Husbandry and his motion that some one be appointed to maintain contact with this movement carried.

The following expression of the Society's appreciation for Charles E. Snyder's efforts in behalf of the Essay Contest was read at the time of the Honor Guest Dinner:

The American Society of Animal Production recognizes the soundness of the objectives of the Saddle and Sirloin Club Essay Contest. Its members have encouraged students to participate in the annual competitions. We believe with Charles E. Synder that the contests have stimulated, encouraged and rewarded good writing on animal husbandry subjects. The Society appreciates that an enterprise such as the Essay Contest requires earnest conviction and persistent effort, given unselfishly, by some one to attain continuity.

The original idea is credited to Mr. R. B. Ogilvie. Under his direction the contest was conducted in 1912 and 1913 with entrants limited to college graduates. After a lapse of 8 years the contest was resumed under the direction of Mr. Snyder with contestants limited to

agricultural college undergraduates in the United States and Canada. Mr. Snyder has guided the project since 1921 with assistance from E. N. Wentworth, E. T. Robbins, W. E. Ogilvie, C. J. Weyker, DeWitt Wing and others.

More than 2,500 contestants have participated. Winners have been announced and awards given at the Society's honor guest dinners for many years. Accordingly it has been the privilege of members of the Society who have attended the dinners to meet the students to whom awards were made.

The Executive Committee has directed the President to express publicly at this dinner the Society's gratefulness to Mr. Snyder, and to those who have assisted him, for inspiring, encouraging and rewarding good writing on animal husbandry subjects.

The Necrology Committee presented memorials for the following deceased members: E. L. Benton, Andrew Boss, C. F. Curtis, G. O. Humphrey and L. A. Richardson.

The Resolutions Committee's report was adopted. It contained the following:

RESOLVED that the Society express its grateful appreciation to the officers and the members of the various committees for their splendid work during the past year;

RESOLVED that the Society record its appreciation for the fine publicity given to the meetings through the untiring efforts of R. C. Pollock and H. H. Biggar of the National Live Stock and Meat Board;

To the Sherman Hotel, the Society expresses its thanks for the facilities and services provided for the annual meeting.

The Society greatly appreciates the courtesy of John Morrell and Company in printing summaries of the papers presented at this meeting. The committee understands that this service will be continued another year. It is a considerable help in following the programs of the sectional meetings.

The following resolution prepared by a Special Committee composed of Louis Hawkins, E. A. Trowbridge, G. Bohstedt, P. S. Shearer, and D. W. Williams, is approved and recommended for adoption:

The American Society of Animal Production in assembly at Chicago, Illinois, November 28 and 29, 1947, publicly recognizes the grave danger to the livestock industry of North America because of Foot and Mouth disease in Mexico. The Society urges exertion of every possible effort by the United States government to eradicate the disease from North America.

The Secretary is instructed to send a copy of this resolution, without delay, to the Honorable Secretary of Agriculture of the United States, to the Chief of the Bureau of Animal Industry, and to the President of the United States Livestock Sanitary Commissioners Association.

The Resolutions Committee was comprised of R. M. Bethke, G. A. Brown, and E. F. Ferrin.

The meeting adjourned about 5:00 P.M.

MEMORIALS

EVERT LOWELL BENTON

Evert Lowell Benton, extension specialist in animal husbandry at Michigan State College, died at 4:30 P.M., Tuesday, April 22, at Sparrow Hospital, Lansing, Michigan, following the third operation within a year.

Mr. Benton was born March 9, 1897, near Dexter, Michigan, the son of Mr. and Mrs. Willis Benton, now deceased. After graduating from Michigan State College in 1930 he taught vocational agriculture at Hudson for five years. From 1935 to 1938 he served as agricultural agent in Tuscola County. In 1938 he joined the animal husbandry department at Michigan State College as extension specialist and served in that position until his death.

Mr. Benton was a member of Alpha Zeta, honorary agricultural fraternity, and had served as secretary of the Michigan Cattle Feeders Association, the Michigan Lamb Feeders Association, and the state Bangs disease committee. He was Sunday School Superintendent at Peoples Church, East Lansing, for many years.

ANDREW BOSS

Death came on January 13, 1947, to Dr. Andrew Boss, 79, University of Minnesota professor emeritus. Dr. Boss was born on June 3, 1867, in Wabasha County, Minnesota and had been a regular member of the University staff since May 1, 1891, when he became farm foreman. Through the years he rose steadily in rank and responsibility, becoming assistant agriculturist in 1894, associate professor of agriculture in 1902, professor of agriculture and animal husbandry in 1905, professor of agronomy and farm management in 1910, and vice director of the experiment station in 1917. Thus for more than 45 years he had been a pioneer and leader in agricultural teaching and research and a trusted friend and counselor of northwest farmers, known personally to thousands and by reputation to hundreds of thousands more, not only through his official capacity with the college and experiment station, but also through his writings for farm papers and his service to farmers' organizations, such as the Minnesota Livestock Breeders' Association, and the Minnesota Crop Improvement Association, both of which he served as secretary for many years.

During the period through which he served as head of the Animal Husbandry Department, Dr. Boss had a leading part in starting several lines of teaching and research which have since become nation-wide in scope. From a course in the dressing and curing of meats, which he developed for the School of Agriculture, have come the modern courses in meats now offered by agricultural colleges all over the country. Dr. Boss was honor guest of the Society in 1929.

Too busy with teaching and research to take even a bachelor's degree during his early years at the University of Minnesota, Professor Boss was honored by Kansas Agricultural College in 1927 with a degree of Doctor of Science. His own University conferred upon him a similar degree in 1945. He was a member of many learned and honorary societies, among them the American Farm Management Association, of which he was a past president; the American Society of Agronomy; American Farm Economic Association; American Association for the Advancement of Science; Sigma Xi; Alpha Zeta; and Gamma Sigma Delta.

CHARLES FRANKLIN CURTISS

Dean Emeritus Charles Franklin Curtiss of the Division of Agriculture, Iowa State College, died at Ames, Iowa, July 30, 1947. Dean Curtiss was reared on a farm in Story County just ten miles from the Iowa State College Campus. He was awarded the Bachelor of Science degree by the College in 1887 and the Master of Science degree in 1892. The Doctor of Science degree was conferred on him by Michigan State College in 1907. He became a member of the Agriculture staff of Iowa State College in 1891, was named Director of the Agricultural Experiment Station in 1897, and was appointed Dean of the Division of Agriculture in 1900. He served in these capacities until 1933 when he gave up administrative responsibilities and was appointed Dean Emeritus of the Division of Agriculture.

Prominent as a purebred livestock producer in his own right, he was influential in founding

the International Livestock Exposition at Chicago, served as its president and continued through the years as a member of its Board of Directors and Executive Committee. He served also as president of the American Berkshire Association, as president of the American Shropshire Association, as an executive of the National Society of Livestock Records Association, as a director and chairman of the Executive Committee of the Percheron Society of America, as president of the American Society of Animal Production, and was Honor Guest of this Society in 1925. During the period of more than 50 years in which Dean Curtiss served Iowa State College and Iowa agriculture, he contributed very significantly to the agricultural development of the state and of the nation. He gave dignity to agricultural education and agricultural research at a time when this was most needed.

GEORGE C. HUMPHREY

George Colvin Humphrey was born in Lenawee County, Michigan, February 13, 1875. He was brought up on a farm, gained his early schooling at a county school, and entered the Michigan Agricultural College in the fall of 1893 with the idea of fitting himself to become a practical stockman. After completing two years of the four years course he left college temporarily to manage his father's farm, but returned and completed his course in 1901. That fall he was called back to act as Instructor in Animal Husbandry in the Agricultural Department at his Alma Mater, which office he filled until elected to the position of Animal Husbandman in the College of Agriculture of the University of Wisconsin, September 1, 1903, which position he held until he retired July 1, 1942.

During this long career at Wisconsin College his time was divided between instruction, extension and research. One of Professor Humphrey's outstanding achievements was his work with county and local livestock breed associations. Professor Humphrey traveled extensively outside the United States. The summer of 1922 he was invited to judge dairy cattle at the great Polermo livestock show, and in 1928 he judged cattle in Hawaii. The summer of 1939 he made a study of livestock conditions in Great Britain and Western Europe where in June of that year he attended the 100th anniversary show of the English Royal Livestock Show at Oxford. In 1935 Professor Humphrey was this Society's Honor Guest.

Professor Humphrey's death occurred as he would have planned it had it been given him to arrange. In apparent good health to the end, he addressed a Farm Bureau meeting in his home community of Ludington, Michigan, the evening of June 17 and passed away quietly in his sleep the early morning of June 18, 1947. Commenting on Professor Humphrey, an early alumnus of the University of Wisconsin wrote: "Of course I feel the loss of one of my best friends, a man who has meant as much to me as any man I know. He leaves, however, about as much as any man can leave, a record of accomplishments and a set of ideals that are worth while."

L. A. RICHARDSON

L. A. Richardson, University of Tennessee Agricultural Extension animal husbandman since 1919, died of a heart attack September 8 while on vacation with Mrs. Richardson and daughter, Lois, in Parkersburg, West Virginia. "Rich," as the veteran livestock specialist was known throughout the Southeast, had spent 32 years in Agricultural Extension work, 28 of them in Tennessee. He was born near Richardsonville, W. Va., in December, 1887 and is a product of Bucknell University and Ohio State University.

It was Richardson's aim to build up the beef cattle, hog, and sheep industries in Tennessee for greater self-sufficiency. He was devoted to a program seeking to provide good animals, good profits to producers, and an ample home meat supply. Linked with this interest was one of good livestock feeding and breeding in a sound, balanced farm program. The influence of his extension work is felt in every county of Tennessee. In his days at Bucknell, Richardson was selected for Walter Camp's third All-America football team. He coached freshman football at Ohio State, and kept in touch with the game by officiating in high school and college games after moving to Tennessee. Mr. Richardson is survived by his widow, Mrs. Lois Richardson, two sons and two daughters.

CHAIRMEN OF COMMITTEES, PROGRAM CHAIRMEN AND SPECIAL REPRESENTATIVES FOR 1948

Standing Committees

Committee on Investigation ..... Wise Burroughs
Committee on Instruction ..... E. H. Hughes
Committee on Extension ..... M. W. Muldrow
Committee on Membership ..... W. G. Kammlade

Special Committees

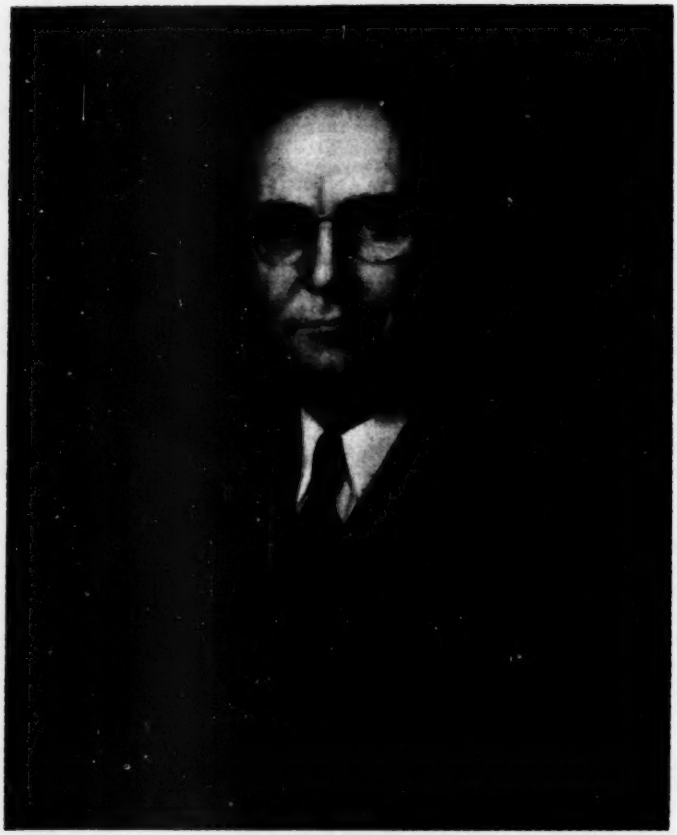
Committee on Pasture and Range Investigations ..... G. O. Mott
Committee on History of Livestock ..... E. N. Wentworth
Committee on Information ..... R. C. Pollock
Committee on Necrology ..... S. S. Wheeler
Nominating Committee ..... A. D. Weber
Committee on the Morrison Award ..... W. G. Kammlade
Committee on American Feed Manufacturers' Award in Nutrition ..... H. R. Guilbert
Committee on Membership in Institute of Biological Sciences ..... T. S. Hamilton
Committee on Publication of Monographs ..... G. Bohstedt
Committee on Amending Constitution ..... W. G. Kammlade

Program Chairmen

Breeding and Genetics Section ..... A. B. Chapman
Extension Section ..... M. W. Muldrow
Meats Section ..... K. F. Warner
Nutrition Section ..... T. J. Cunha
Pasture and Range Section ..... G. O. Mott
Physiology Section ..... A. V. Nalbandov
Teaching Section ..... E. H. Hughes

Special Representatives

Inter-Association Council ..... E. A. Livesay
Science Legislation ..... H. C. McPhee
Council of American Association for Advancement of Science ..... F. F. McKenzie
Division of Biology and Agriculture, National Research Council ..... H. W. Marston
International Animal Husbandry Association ..... R. W. Phillips



GEORGE H. HART

Reproduction of a portrait presented to the Saddle and Sirloin Club in Chicago by the American Society of Animal Production on November 30, 1947. George H. Hart was the Honor Guest of the Society during its annual meeting which was being held at that time.

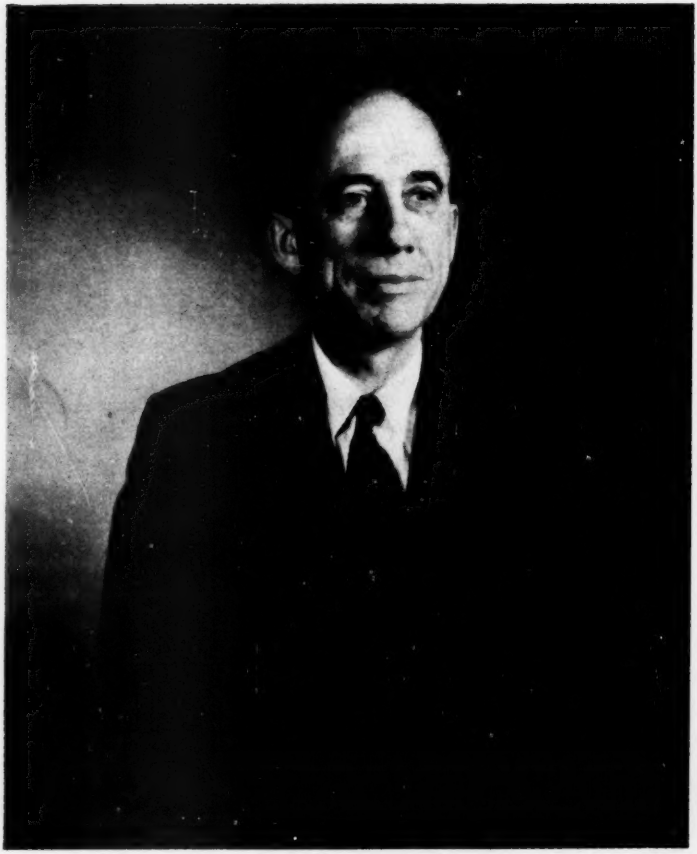
GEORGE H. HART

Honor Guest—1947

As a keen investigator, an inspiring teacher, an able administrator, and an eminent public servant with a deep appreciation of the practical aspects of animal husbandry, the name of George H. Hart has been intimately associated with the improvement of the livestock industry for more than forty years. His brilliant mind, coupled with a deep natural curiosity has given him the ability to conceive and direct productive research. Always facing the problems of the livestockman squarely, he is intolerant of tradition. He arrives at important decisions with wisdom and common sense.

George Hart was born October 10, 1883 on a livestock farm near Philadelphia where he spent his boyhood. After graduating from the University of Pennsylvania Veterinary School in 1903, he continued his studies at George Washington University, where he was graduated with the degree of Doctor of Medicine in 1908. While pursuing his medical studies, he served in the Bureau of Animal Industry of the United States Department of Agriculture as assistant bacteriologist and pathologist. In 1908 Dr. Hart went to California, where he spent two years in the fight to eradicate the Texas fever tick. After seven years as Veterinarian for the City of Los Angeles, he joined the staff of the Veterinary Division of the University of California. Here he conducted significant research on bovine tuberculosis and brucellosis. For the past twenty years he has been Professor of Animal Husbandry and Head of the Animal Husbandry Division of the University of California, in which capacity he has proved himself an able administrator. Here he organized a sound research program based on the concepts, revolutionary at the time, that most of the problems of Animal Husbandry fall into three distinct fields—genetics, nutrition, and physiology, and that the exact methods of measurement and analysis used in the laboratory must be applied to the solution of practical problems in the field. Eighty-two publications, of which Dr. Hart is author or co-author, appear in the Library of the University of California. These include significant papers in nutrition, physiology, bacteriology, genetics, and pathology. Few men have made such outstanding contributions in so many fields of biology.

The almost boyish enthusiasm with which he approaches a problem, the relentless drive he applies to its solution, and his ability to impart these attributes to his colleagues are in a great measure responsible for the accomplishments of the Division of Animal Husbandry under his leadership. His name will stand high among those responsible for instituting a sound and broad program of research in the field of livestock production.



WAYNE L. ROBISON

Wayne L. Robison was awarded the second Morrison Award which was presented to him during the 39th annual meeting of the American Society of Animal Production in Chicago on November 29, 1947.

THE MORRISON AWARD

1947

The Award Committee of the American Society of Animal Production has selected Mr. Wayne L. Robison, of the Ohio Agricultural Experiment Station, to receive the Morrison Award for 1947.

The winner of the Award is a leading authority in the field of swine production. His contributions have been made in the fields of feeding, breeding, effect of ration on carcass and hardness of the fat, and management practices. Doubtless the field of improving swine rations, particularly supplements to corn—both kind and amounts—for use in dry lot and on pasture, has been his major contribution.

When the soybean crop came into the picture, his early work showed the importance of the application of heat in the manufacturing process of soybean oil meal. Continued work with soybean oil meals have progressed to the point where soybean oil meal can be fortified to make it a most satisfactory supplement for corn. Work done comparing dry rendered tankage with digester tankage has had lasting effect upon tankage production methods and upon swine rations. His work with cottonseed meal has been helpful in showing causes of cottonseed poisoning in pigs and methods of treating the meal to make it an acceptable ingredient in swine rations.

The value of pasture in swine feeding and the relative value of various pasture crops has received major attention, with beneficial results to the industry. Mr. Robison was also a member of a team that studied causes and worked out methods of preventing crampiness (paresis) in swine.

As a cooperator in the swine breeding laboratory, his work is contributing toward the progress of this research. Improvement in management practices and swine equipment have been more than a hobby with this investigator. The herd of Durocs which he had developed over the past thirty years at the Ohio Agricultural Experiment Station has received special recognition by the breed association.

Mr. Wayne L. Robison was born on a farm in Indiana and graduated from Purdue University. He received the master of science degree from The Ohio State University, and since 1915 has been in charge of swine investigations at the Ohio Agricultural Experiment Station.

NEWS AND NOTES

The Society has available the following numbers of complete volumes and individual copies of the JOURNAL OF ANIMAL SCIENCE:

Volume	Year	Complete volumes	Copies of numbers in addition to complete volumes			
			No. 1	No. 2	No. 3	No. 4
1	1942	38	None	72	77	97
2	1943	110	45	20	None	12
3	1944	18	61	None	23	27
4	1945	None	2	None	None	None
5	1946	42	None	28	35	11
6	1947	Approx. 100				

The above are for sale by the Business Manager of the JOURNAL, W. G. Kammlade. Each complete volume is $3.50 and each single copy $1.00 in the United States. Prices elsewhere will be sent on request.

The Society also has available the following copies of the Proceedings of the American Society of Animal Production:

Year	No.	Year	No.
1915–16	65	1931	80
1920	13	1932	34
1922	374	1933	52
1923	249	1934	53
1924	—	1935	54
1925–26	68	1936	12
1927	66	1937	—
1928	2	1938	9
1929	48	1939	26
1930	34	1940	83

These are also for sale by the Business Manager of the JOURNAL, and prices for the various years may be obtained from him.

Mimeographed copies of the papers presented in the Opening Session of the Thirty-Ninth Annual Meeting of the American Society of Animal Production may be obtained from the respective authors by those desiring copies for reference purposes. The papers and authors were as follows: "The National Land Use and Conservation Policy" by R. M. Salter of the U. S. Department of Agriculture; "Changes Expected as to Kind, Quantity and Quality of Feeds" by E. A. Trowbridge of the University of Missouri; "Adjusting Animal Populations, Feeding and Management Practices" by F. B. Morrison of Cornell University; and "Changes Expected in Animal Production in the South" by J. H. Hilton of North Carolina State College. Mimeographed copies of these addresses may be obtained from the authors.

A Congress on the Physio-pathology of Reproduction will be held in Milan, Italy, during the period June 23–30, 1948, under the auspices of the University of Milan and the Spallanzani Institute for Artificial Insemination. Any members of the American Society of Animal Production wishing to present papers should immediately notify the Secretary-General of the Congress, Professor T. Bonadonna, Via Fratelli Bronzettie 17, Milan, Italy. Enquiries may be directed to Professor Bonadonna. Subscription fees are $8.00 for active and $4.00 for associate members. These may be sent direct to the Secretary-General.

A publication entitled "Breeding Livestock Adapted to Unfavorable Environments" by Ralph W. Phillips, Head, Animal Industry Branch, Agriculture Division, was issued by the Food and Agriculture Organization of the United Nations in January. It sets forth the problems encountered in breeding livestock adapted to tropical and subtropical conditions, semi-arid areas, high plateau regions and other areas where nature imposes hardships on livestock. Detailed consideration is given to geographic and climatic limitations upon livestock production, adaptability of sheep to various environments and adaptability of cattle to tropical and subtropical climates. Some material on adaptability of horses and swine is also given, together with discussions of the less-known types of animals used in livestock production, including water buffaloes, yaks, reindeer, camels, dromedaries, llamas and alpacas. This is followed by a discussion of breeding methods that may be used under unfavorable conditions, and some of the basic principles of breeding and their application. The volume contains 182 pages and has 72 illustrations. It may be obtained from the Columbia University Press, International Documents Service, New York 27, N. Y. The price is $1.50.

A new desk dictionary entitled "The American College Dictionary" was published recently by Random House, Inc., New York, N. Y. It is designed for the general reader, student and educator. A special effort has been made to have it accurate and up-to-date in all respects, and particularly with respect to scientific terminology. Over 350 recognized authorities contributed to it, and among them were several members of the American Society of Animal Production, including Damon A. Spencer, Ralph W. Phillips, John H. Zeller, O. E. Read and W. H. Black. This dictionary contained 1,432 pages, is printed on good quality paper, and is priced at $5.00.

The second edition of "The Artificial Insemination of Farm Animals" was published recently by the Rutgers University Press, New Brunswick, New Jersey. The book was edited by Enos J. Perry, and the following contributed to it: John W. Bartlett, Joseph Edwards, Clair E. Terrill, Victor Berliner, Fred P. Jeffrey, J. A. Henderson and Ralph P. Reece. It contains, in addition to introductory chapters dealing with the history and advantages and limitations of artificial insemination, chapters on the organs of reproduction and the role of hormones in reproduction, a general chapter on the collection and handling of semen, one on factors influencing the quality and quantity of sperm, and chapters dealing with the application of the technique to cattle, sheep and goats, horses and jackstock, birds and swine. Other chapters deal with breeding better livestock, systems of breeding, shipping of semen, disease in relation to artificial insemination, and the feeding and management of sires. The chapters on the role of hormones in reproduction and factors influencing the quality and quantity of sperm are new in this edition. The book contains 338 pages, is well illustrated, and should serve as a useful handbook to all who are interested in the application of artificial insemination. The price is $4.00.

P. E. Neale of the Animal Husbandry Department, New Mexico State College, went to the Near East in December, 1947. Professor Neale will spend approximately four months in Egypt, Iraq, Lebanon and Syria working with the governments of those countries on their sheep-breeding problems, under the auspices of the Food and Agriculture Organization of the United Nations.

Arthur T. Semple, superintendent of the Inter-American cooperative experiment station at Tingo Maria, Peru, resigned on December 3, 1947, to join the Agriculture Division of the Food and Agriculture Organization of the United Nations, where he will do range and pasture work in the Animal Industry Branch.

Glenn W. Salisbury, Professor of Animal Husbandry at Cornell University, resigned in November to accept the post of Chairman, Department of Dairy Husbandry, University of Illinois.

Vard M. Shepard, extension animal husbandman at the University of California, resigned on July 15, 1947, to accept the deanship of Agriculture at California State Polytechnic Institute, San Louis Obispo.

John S. Robinson has been promoted to the position of leader of animal husbandry extension at the University of Tennessee, succeeding L. A. Richardson, deceased.

G. B. Phillips, former county agent, has been placed in charge of swine extension work at the Alabama Polytechnic Institute.

Marshall C. Heck, assistant extension animal husbandman in the Arkansas Extension Service, has resigned to accept a position with a commercial firm in Kansas City, Kan.

J. R. Hawkins, extension animal husbandman in the South Carolina Extension Service, resigned January 1, 1948, to devote his time to his farming interests at Lykesland, South Carolina.

J. T. Graves and Walter A. Ridgeway, former county extension workers, have been appointed extension livestock specialists in the South Carolina Extension Service, with headquarters at Barnwell and Newberry, respectively.

J. H. Hilton, head of the Animal Industry Department at North Carolina State College, was made Dean of Agriculture and Director of the Experiment Station at the same institution, effective January 1. He succeeds L. D. Baver, who resigned to become Director of Research for the Hawaiian Sugar Planters' Association in Honolulu.

Sam L. Williams, reported in the last issue as having returned from service in the U. S. Army to his former position as assistant extension animal husbandman in the North Carolina Extension Service, reconsidered in favor of continuing with A.M.G. in Europe.

Howard Dickey has been appointed head of the Animal Husbandry Department, University of Maine, succeeding A. O. Shaw, who resigned to accept a post at Washington State College.

E. Paul Orcutt has returned to his former position of Senior Livestock Specialist, Montana Extension Service, following several years as manager of a large sheep ranch in the state.

Earl R. Garrison has been appointed associate professor of animal industry on the staff of the University of Arkansas, in dairy products work.

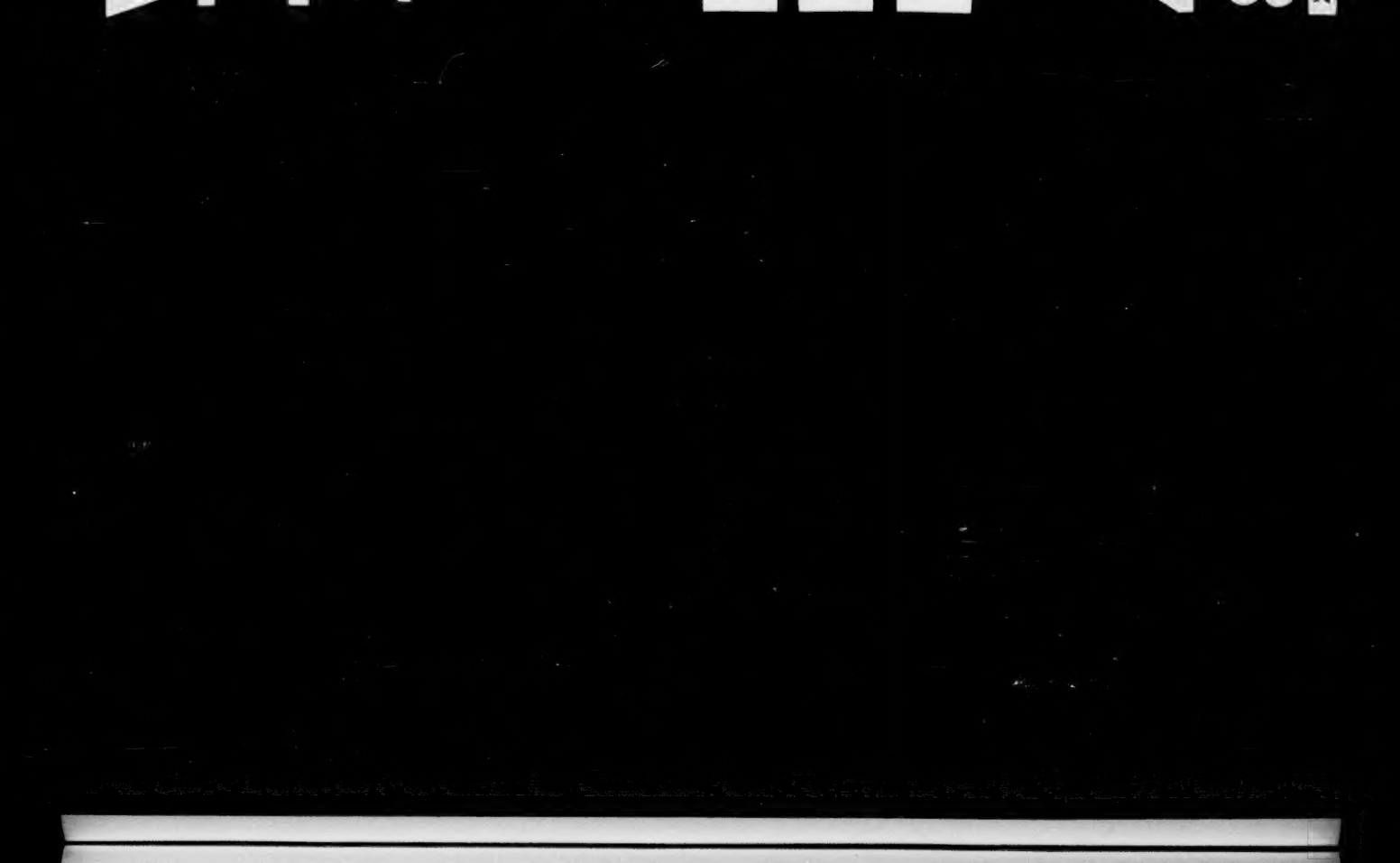
Ray C. Hopper, former county agent, has been made extension animal husbandman in the Kentucky Extension Service to fill the vacancy created by the resignation of Wayland Rhoads.

D. E. Brower was appointed 4-H livestock specialist in the Virginia Extension Service effective January 1, 1948. On the same date W. E. Tyler became full-time instructor on the teaching staff at Virginia Polytechnic Institute, succeeding Mr. Brower.

Malcolm Kerr, former member of the animal husbandry staffs at the University of Tennessee and the University of Connecticut, is now on the animal husbandry staff at the University of Maryland.

George Wellington, formerly of Kansas and Michigan, is now extension meat specialist at Cornell University.

Wells E. Hunt, formerly of the animal husbandry staff at the University of Maryland, and more recently with S-K Packing Company in Baltimore, Maryland, has resigned to become general manager of a meat packing firm in Philadelphia, Pennsylvania.

Carl G. Potts, superintendent of the animal husbandry farm at the U.S.D.A. Agricultural Research Center, Beltsville, Maryland, is recuperating from injuries received in an automobile accident while en route to Chicago in late November.

George W. Snedecor, research professor of statistics at Iowa State College, will be visiting research professor of statistics at Alabama Polytechnic Institute during the spring quarter, from March 22 to June 4, 1948. He will lecture on "Statistical experimental design" and will be available for statistical consultations. The newly formed Statistical Laboratory at A.P.I. will also offer a course in Survey Sampling during the Spring Quarter to be taught by the Director, Professor T. A. Bancroft. Conferences in applied statistics for research workers in the lower southeastern states are being scheduled during the time of Professor Snedecor's visit.